THE UNIVERSITY OF TEXAS BULLETIN
No. 3016: April 22, 1930

GEOLOGY OF BELL COUNTY, TEXAS

By

W. S. ADKINS and M. B. ARICK

Bureau of Economic Geology

J. A. Udden, Director E. H. Sellards, Associate Director

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The benefits of education and of useful knowledge, generally diffused through a community, are essential to the preservation of a free government.

Sam Houston

Cultivated mind is the guardian genius of democracy. . . . It is the only dictator that freemen acknowledge and the only security that freemen desire.

Mirabeau B. Lamar

CONTENTS

ILLUSTRATIONS

Plates

Figures

GEOLOGY OF BELL COUNTY, TEXAS*

By W. S. ADKINS and M. B. ARICK

INTRODUCTION

The region near Bell County was traversed by various expeditions during the Eighteenth Century: Marqués de Aguayo in 1721, De Mézières in 1779, and Vial in 1786. The Aguayo expedition crossed the Colorado near Austin, the Little River near Belton, and the Brazos near Waco.[1] Much early historical information on central Texas is summarized in the work by Bolton.[2] Of especial interest for the Spanish history of this region is his account of the San Xavier mission, founded in 1746 in western Milam County.[3] The late Judge George Tyler of Belton prepared a manuscript covering the general history of Bell County, which is now in the University of Texas archives.

There are no records of extended geological investigation in the county earlier than R. T. Hill and the geologists of the Dumble Survey. W. P. Riddle and others of the Shumard Survey did geological work in this county just before the Civil War,[4] and about 1875 Mr. D. H. Walker collected from Salado and elsewhere Washita fossils, which were sent to the Smithsonian Institution and which later were described by C. A. White.[5] Some Bell County fossils were still later described by Hill.[6]

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*Printed July, 1930.

[1]Buckley, Eleanor Claire: The Aguayo Expedition into Texas and Louisiana. Texas State Historical Association Quarterly, XV, No. 1, July, 1911. Peña: Derrotero de la expedición en la provincia de los Texas. México, 1722 (transcript in The University of Texas Library).

[2]Bolton, Herbert Eugene: Texas in the Middle Eighteenth Century. Univ. Calif. Publ. History, Vol. III, Berkeley 1915.

[3]Bolton, *ibid.*, pp. 135–278, map on page 229. Review in Texas Hist. Qt., XIX, p. 320.

Bolton, H. E., 1914. Founding of the Missions on the San Gabriel River. Texas Hist. Qt., XVII, pp. 323–378.

[4]Shumard, B. F., 1860, Trans. Acad. Sci. St. Louis, I, 586.

[5]White, C.A. United States Geol. Geogr. Survey. Terr., 11th Ann. Rept. for 1877, pp. 278, 297, Washington, 1879. White, same survey, 12th Ann. Rept., pp. 22, 23. White, Proc. U.S. Nat. Mus., II, 297, 1880. White, 1888, U.S. Geol. Surv., 4th Ann. Rept., pp. 304, 307.

[6]Hill, R. T., 1893. Proc. Biol. Soc. Wash., VIII, pp. 97–108, pls. XII–XIII.

In April, 1889, Dr. R. A. F. Penrose, Jr., assistant geologist of the Dumble Survey in charge of East Texas, made two short trips northwest and southwest of Belton. These investigations were apparently incidental to his river trips across the iron ore districts in East Texas.[7] Seventeen pages of handwritten notes by Penrose on the western part of Bell County, dated April 6, 1889, contain interesting geological observations, and will be mentioned later. The present field work was done at various times from 1923 to 1929, but mainly from December, 1928, to May, 1929.

Information on the geology of Bell County and immediately adjacent districts is contained in the following papers:

Taff, J. A., 1892. Reports on the Cretaceous area north of the Colorado River. Part II, The Lampasas-Williamson section. Geol. Surv. Texas, 3d Ann. Rept., pp. 269–379.

Taff, J. A. and Leverett, S., 1893. Report on the Cretaceous area north of the Colorado River. Geol. Surv. Texas, 4th Ann. Rept., pp. 239–354.

Hill, R. T., 1901. Geography and geology of the Black and Grand Prairies, Texas [etc.] U. S. Geol. Surv., 21st Ann. Rept., pt. 7.

Paige, Sidney, 1912. U. S. Geol. Surv., Geol. Folio No. 183 (Llano-Burnet).

Adkins, W. S., 1924. Geology and mineral resources of McLennan County. Univ. Texas Bull. 2340.

Sellards, E. H., 1925. Geologic section in Milam County. Bureau of Economic Geology, mimeogr. circular.

Sellards, E. H., 1925. Geologic section in Williamson County. Bureau of Economic Geology, mimeogr. circular.

Adkins, W. S., June, 1929. Mineral Resources: Bell County. Bureau of Economic Geology, reprint, 16 pp.

Well records of Bell County. Bureau of Economic Geology, mimeogr. circ. no. 6, 19 pp., June, 1928.

Sellards, E. H., 1929. Preliminary map of underground position of pre-Cambrian in Texas. Bureau of Economic Geology, mimeogr. circ. no. 9.

Stephenson, Lloyd W., 1927. Notes on the stratigraphy of the Upper Cretaceous formations of Texas and Arkansas. Bull. Amer. Assoc. Petr. Geol., XI, 1–17.

Stephenson, Lloyd W., 1928. Major marine transgressions and regressions and structural features of the Gulf Coastal Plain. Am. Jour. Sci., XVI, 281–297.

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[7]Dumble, E. T., 1890. Geol. Surv. Texas, 1st Ann. Rept., p. xxvi.

Stephenson, Lloyd W., 1928. Correlation of the Upper Cretaceous or Gulf series of the Gulf Coastal Plain. Am. Jour. Sci., XVI, 485–496.

Stephenson, Lloyd W., 1929. Unconformities in Upper Cretaceous series of Texas. Bull. Amer. Assoc. Petr. Geol., XIII, 1323–1334.

Dane, C. H. and Stephenson, L. W., 1928. Notes on the Taylor and Navarro formations in east-central Texas. Bull. Amer. Assoc. Petr. Geol., XII, 41–58.

Cheney, M. G., 1929. Stratigraphic and structural studies in north-central Texas. Univ. Texas Bull. 2913.

Some maps which include part or all of Bell County are:

Map of commissioners' districts 1–4, Bell County, Texas. A. M. Monteith Abstract Company, Belton. 4 sheets. Scale: 1,000 varas = 1 inch.

Bureau of Soils. Carter, William T., Jr., Lewis, H. G. and Hawker, H. W., 1918. Soil survey of Bell County, Texas. Soil map of Bell County. Scale: 1:63 360. Surveyed in 1916.

Deussen, Alexander, 1924. U. S. Geol. Surv., Prof. Paper 126, pl. VIII.

Post Office Department: Rural delivery routes, Bell County, Texas. Scale: 1:63 360.

State Land Office: Land map of Bell County, 1896. Scale: 2000 varas = 1 inch.

Taff, J. A., 1893. Geol. Surv. Texas, 3d Ann. Rept., pl. X. Scale: 4 miles = 1 inch.

State of Texas, Board of Water Engineers, and United States Geological Survey. Advance sheets:

Temple 2-c, 488–S–II–W/2–SW/4.
Temple 3-b, 488–S–IV–W/2–NW/4.
Temple 3-c, 488–S–IV–W/2–SW/4.
Gatesville 4-a, 488–S–III–E/2–NE/4.
Gatesville 4-d, 488–S–III–E/2–SE/4.

Scale: 1:48 000; contour interval, 20 feet.

Belton Reservoir Site. 97° 22′ 30″-97° 30′ 30° 57′ 30″-31° 05′. Scale: 1:24 000; contour interval 10 and 20 feet; surveyed 1923–1924.

United States Geological Survey, Topographic sheets. Scale: 2 miles = 1 inch; contour interval, 50 feet.

Waco sheet.
Temple sheet.
Gatesville sheet.

STRATIGRAPHIC GEOLOGY

The surface formations in Bell County are of Comanchean and Upper Cretaceous (Gulf Series) age, Glen Rose to Taylor inclusive. These are irregularly mantled by Pliocene (?) and Pleistocene gravel, sand and clay, and by Recent gravel and soil.

The subsurface formations which have been recognized in Bell County include basal Comanchean formations (Glen Rose, Travis Peak); Pennsylvanian sandstones and other sediments of Strawn age; black fossiliferous shales possibly of Bend age; questionable Cambro-Ordovician (Ellenburger) limestone; and a series of black, mainly unfossiliferous, metamorphosed shales alternating with dark-colored quartzites, and underlain by gray, green and maroon shales with some quartzites, cherts, sand, and sandstone. These metamorphosed rocks are of unknown age, probably Paleozoic.

PRE-CRETACEOUS FORMATIONS

PENNSYLVANIAN

STRAWN SERIES

West of this county, the wells drilled near Copperas Cove have a thick, normal succession of Strawn. Teinert No. 1 has about 1900 feet of Strawn; Gotcher No. 1 about 1700 feet; Strickland No. 1 about 1600 feet. The Thomas Young well, near the Bell-Coryell county line north of Killeen has Strawn from 1135 feet to the total depth, 2895 feet, a total of 1760 feet. These beds consist of sandstones, bearing water and traces of oil, sandy clays, blue, black and salty shales and clays, and gray and black limestones, in thin-bedded and alternating succession. Eastward across Bell County the Strawn thins very rapidly. This belt might be the stripped zone of the coast of the old land of Llanoria, assuming that Strawn sediments originated from an eastern land-mass. In central Bell County rocks referred to the Strawn have been recognized in the Swope No. 1 (from the dump); and very problematically from the Kolls 4, Down, Perry and Hughes (this rock, from similarity to the nearby

Hair well, is probably from the black shale and quartzite series, Group I). Following is a description of this sample from the Swope well:

A lump about 3 inches by 2 inches of micaceous gray sandstone, containing some pyrite and showing some peculiar bedding marks, which on one side of the rock suggest irregular ripple marks. This piece of rock resembles sandstone from the Strawn. (J. A. Udden.)

BEND SERIES

The Bend is typically developed in western Coryell County, and doubtless also in the undrilled westernmost part of Bell County. Near Copperas Cove the Teinert No. 1 well has 430(?) feet of Bend, the Gotcher No. 1 well 125 feet, the Strickland No. 1 well 375 feet of Smithwick and 140 feet of Marble Falls. The Bend must thin very rapidly on passing eastwards across Bell County or else be beveled off by subsequent (pre-Cretaceous) erosion, for in only a few scattered wells in the central strip in Bell County are there brief records of it. In Slayden No. 1 at 1000 feet is a fossil-bearing dolomitic(?), bituminous, slightly glauconitic black limestone with siliceous replacement; the fossils mentioned are sponge spicules, crinoid stems, bryozoon fragments and shells of ostracoda. The nearby Sladen No. 2 well contains maroon and greenish indurated shale with radiolaria and sponge spicules, which has been tentatively assigned to the Bend by some writers, but which is here correlated with Groups V–VI in the Bailey well, of unknown age. Other samples from central Bell County which have been problematically assigned to the Bend mainly on the basis of supposed lithologic resemblance, include: Kolls, Petoskey No. 1, 1170–1198 feet, which probably belong to "Group 1, black shale-quartzite series" known to be present on the same property a few feet from this well; and Epperson No. 1, depth of sample 722 feet, described as follows:

Pieces of greenish-gray calcareous shale. Calcite and a little pyrite were noted in the washed material. Crinoid stems and smooth ostracoda present also.

Other problematical Bend assignments, made on lithologic resemblance alone, are samples from Bacon No. 1 at 1107–1170, variously described as "slaty" or "schistose?" shale; and Bacon No. 2, samples at 1060 and 1510–1550, described as "indurated black shale." The age of these samples is unknown; they may belong to the black shale-quartzite series.

CAMBRO-ORDOVICIAN

ELLENBURGER

The Ellenburger formation outcrops in Burnet County about 24 miles west of the western boundary of Bell County. In Coryell County, just north of the western part of Bell County, Ellenburger occurs: in the Teinert well at the depths 3579–3600 feet; in the Gotcher well at 3035–3092 feet; in the Strickland well at 3615–3628 feet. It thins, or else has been removed by subsequent erosion, in passing eastwards across central Bell County, and is not definitely known in Bell County.

METAMORPHOSED PALEOZOICS (?)

Knowledge of the exact succession of older rocks beneath Bell County is defective, both because of the lack of properly located deep wells and because of scanty information about those already drilled. The pre-Cretaceous basement in Bell County, as in McLennan County, is enormously complicated, and would if stripped of its Comanchean cover, appear as a patchwork of folded and faulted Paleozoic and possibly pre-Paleozoic formations. From the amount of shearing, slickensides, jointing, and metamorphism revealed in well samples, it is evident that a portion of the basement rocks in central Bell County has participated in severe mountain-making movements.

Wells in southwestern Coryell County (and likely the yet undrilled westernmost part of Bell County) pass through a normal succession of Paleozoic rocks as seen in the Central Mineral Region, including Strawn, Bend and Ellenburger.

Of Bend formations, the Smithwick shale, Marble Falls limestone, and Barnett shale, are recognizable. Such wells are Teinert 1, Gotcher 1, and Strickland 1, here used for comparison. East of these, in west-central Bell County, are the wells already discussed which seem to contain slight remnants of identifiable Paleozoic formations. Farther east, running across central Bell County west of Belton and with a general Appalachian strike, is a strip of territory in which the Comanchean is directly or almost directly underlain by a series of somewhat metamorphosed sediments here referred to as the "black shale-quartzite series." This formation is widespread in this strip, in Travis, Williamson, Bell, McLennan and other counties, and is of unknown age. It constitutes one of the most important stratigraphic problems in the area, and has been the subject of much speculation. The following discussion attempts to interpret the known facts about its stratigraphy in Bell County.

The Noah Bailey No. 1 well penetrated the greatest thickness of pre-Comanchean rocks yet explored in Bell County, a thickness of about 2992 feet. This is the only well which has completely passed through the black shale-quartzite series, and the section serves as a reference point for locating that series stratigraphically. The pre-Comanchean rocks in the Bailey well may be divided and summarized as follows:

Pre-Comanchean Section in Noah Bailey No. 1, Bell County, Texas

Group		Depths	Thickness Feet
I.	Shale, black, indurated, somewhat metamorphosed, alternating with gray quartzite; no red or green, no chert. Black shale-quartzite series	800–2640	1840
II.	Same, but with red and green shale, green chert; fossils: spicules, oval bodies, spherical bodies	2640–3050	410
III.	Dark, silty shale, with a little quartzite basally; no red or green, no chert	3050–3170	120
IV.	Mostly red-maroon shale; some green and gray shale; no chert. Red shale series	3175–3500	325
V.	No red material; hard, dark gray, some green chert; radiolaria?	3500–3580	80

Group		Depths	Thickness Feet
VI.	Red, green and gray shales; green and black chert basally (past 3655)	3590–3695	105
VII.	No green or red material; mostly flint and cherty shale	3695–3790	95

Apparently, from logs and samples, no other well yet drilled in the county has completely penetrated the black shale-quartzite series. The following are the probable thicknesses of this series penetrated in Bell County wells:

Well:	Depths	Thickness Feet
Bailey 1	800–2640	1840
Warrick-Hartman	973–2772	1800
Holcomb 1	1105–1640?	535?
Winans and Forbes 1	821–1780	959
D. W. Hair 1	1157–2002	845
Kolls, Down, Perry and Hughes	1194–1445	451
Stansfield	1200–1510	310
Bacon 2	1500–1800?	300?

Presumably in central Bell County this series (Group I) has a thickness of 1800 feet or more, and the wells drilled into it, except the Bailey 1, did not reach the base of the series.

The attitude of this group of rocks may be obtained through a provisional correlation between Bailey 1 and the Slayden No. 2 well, about 4½ miles west of it. In Slayden 2, beneath the base of the Comanchean at 811 (or 830) feet, are green, red, and gray, veined, indurated shales, with quartzites and cherts. Upon two striking features a purely provisional and hypothetical correlation is made between the two wells:

(a) *Radiolaria?* (and sponge spicules) are prominent in Slayden 2 at 850–950 feet. The only levels at which they are recorded in Bailey 1 are in Groups V–VI (3500–3695 feet).

(b) The succession of rocks in Slayden 2, at 935–1050 feet, is too strikingly similar to that in Groups VI (basal part) and VII of the Bailey well to be pure coincidence. In each well, green and red shales are succeeded downwards by a preponderance of black and green chert, and still deeper by abundant black flint, the main feature of Group VII.

Provisionally assuming this correlation, the strata in Slayden 2 at 850–1050 are equivalent to Groups VI–VII at 3550–3750 in the Bailey well. This would mean that in the Slayden well the upper succession (I–V) vas planed off by pre-Comanchean erosion, and that between the two wells the Groups VI–VII dip eastwards 2700 feet in 4½ miles, a dip of about 600 feet per mile. According to this theory the black shale-quartzite series (Group I) thins westwards across Bell County by having been beveled off, and south of Killeen it has all been removed. East of the Balcones Fault zone, Group I presumably thickens, but has not been reached by the drill. Group I is known in wells from the southern boundary of Bell County (Warrick wells) to near the northern boundary (Stansfield well near Bland).

On going west difficulties to this interpretation appear, especially in connection with Bacon Nos. 1 and 2, located 3.9 miles west of Nolanville. These two wells are located on the same tract, but their records are incomplete and contradictory. The crucial point is the questionable occurrence of Ellenburger at 1100 feet, and in some deeper samples in Bacon No. 2, as quoted under the discussion of Ellenburger.

Samples in Bacon Nos. 1 and 2, Bell County, Texas

BACON 1	
1107	Black shale.
1100–1110	Very black, *slaty* shale.
1170	Gray, *schistose?* shale, and black shale.

BACON 2	
1060	Indurated black shale.
1100	"Crystalline rock"; may be Ellenburger.
1500–1510	Dark greenish-gray crystalline rock.
1510–1550	Crystalline rock (like 1500–1510) and *indurated* shale (like 1060).
1805	Dark, green and gray crystalline rock.
1810	Very dark, slightly greenish *crystalline rock* containing biotite?
1815	like 1810, *crystalline rock.*
1820	like 1810, *crystalline rock.*

Dr. E. H. Sellards states that the black shale taken from these wells is lithologically typical of Group I. The "crystalline rock" is apparently metamorphic. It would appear that this record should be discarded as evidence for the presence of Ellenburger.

Age of Group I: The age of these rocks is unknown. Such rocks from Bell and nearby counties have been considered pre-Cambrian, as Pennsylvanian of the eastern (Ouachita) facies, or even as Middle Paleozoic.[8]

The following are arguments for the Paleozoic, rather than pre-Cambrian age:

(1) The rocks are unlike those found in the deep wells in Caldwell County, and are less metamorphosed.

(2) They are unlike the known pre-Cambrian from the Central Mineral Region.

(3) They are somewhat similar in degree of metamorphism to several Paleozoic rocks, notably those of the eastern (Ouachita) facies of the Oklahoma Paleozoic.

(4) The degree of softness found in some of them *(e.g.,* semi-friable red sandstone in Winans and Forbes No. 1, at 1309 feet) is unusual in the pre-Cambrian but usual in the Paleozoic.

(5) Colors: more usual in the Paleozoic.

(6) Fossils: sponge spicules, radiolaria?; usual in the Paleozoic, unknown in the Texas pre-Cambrian (but occur in pre-Cambrian at some places).

(7) Oil shows: rare or generally lacking in pre-Cambrian.

More specifically, the age of rocks of Group I, if Paleozoic, is almost wholly conjectural. *(a)* In central Texas there is no clear evidence that they anywhere underlie the Ellenburger. Even if they do, their age might be Ordovician or Cambrian. *(b)* If they overlie the Ellenburger, they may be of any age from Ordovician to Cretaceous.[9] Such evidence as exists favors their correlation with pre-Bend, early or middle Paleozoic. The green cherts are suggestive of Simpson (Ordovician) but similar cherts appear as high as the Santiago chert level in the Marathon basin. This correlation awaits the discovery of more fossils.

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[8]Stanley and Woodford (Cheney).

[9]The maroon shales strikingly resemble the West Texas non-marine Dockum beds hitherto referred to the Triassic; some of the black shales could be matched from the Lower Jurassic (Liassic) "slates" bordering the Mesa Central in the states of Puebla and Hidalgo, Mexico, the upper Jurassic (Kimmeridge) folded and indurated shales near Tamazunchale, southern San Luis Potosi, or even the Lower Cretaceous Necoxtla slates northeast of Mexico City.

Some Silurian rocks in eastern Oklahoma have similar lithology and metamorphism. If rocks of Group I are equivalent to the Bend, then they change lithology over the distance of 9 miles from Smithwick eastwards to the Sunset (Evans) well west of Leander. If they are equivalent to the Strawn, which is typically developed to the west of them but which presumably had its source to the east, off Llanoria, then the main differences from the Strawn are to be accounted for by either a change of facies (more clastic shorewards, probably) or by metamorphism, or both. If they are not the Strawn, then presumably their junction with the Strawn in western Bell County is marked by a considerable fault. In any event their junction, to the east, with the phyllites and varied metamorphic rocks of buried Llanoria, is by a large fault. It is a possible speculation, therefore, that this strip of metamorphosed shales and quartzites in central Bell County is part of a faulted block of considerable size. This structurally disturbed zone is in general alinement with an overturned zone proposed by Cheney in southern McLennan County, based on supposed repetition of Bend in the Stewart well near McGregor.

Origin of Metamorphosed Rocks: It is currently assumed that the source of much of the Pennsylvanian sediments in the counties just west of Bell County was the old land mass Llanoria,[10] which remained emerged through much of Pennsylvanian time and discharged sediments westward and northward into Bend, Strawn, and later Pennsylvanian seas. The great accumulation of Strawn and later Pennsylvanian sediments indicates a considerable geosyncline bordering the

[10]Miser, Hugh D., 1921. Llanoria, the Paleozoic land area in Louisiana and eastern Texas. Am. Jour. Sci., (5), II, no. 8, 61-89. Sellards, E. H., 1929. Preliminary map of underground position of Pre-Cambrian in Texas. Circ. No. 8, Bureau of Economic Geology, Austin. Cheney, M. G., 1929. History of the Carboniferous sediments of the Mid-Continent Oil Field. Bull. Amer. Assoc. Petr. Geol., 13, no. 6, 557-594. Cheney, M. G., 1929. Stratigraphic and structural studies in north-central Texas. Univ. Texas Bull. 2913. Honess, C. W., 1928. Geology of the southern Ouachita Mountains of Oklahoma. Okla. Geol. Surv., Bull. 32, part I. Sellards, E. H., 1930. Pre-Cretaceous rocks of the Balcones Fault Zone of Texas. 15th Ann. Meeting Amer. Assoc. Petr. Geol., New Orleans, March 20-22, 1930, program, page 5. Miser, H. D. and Sellards, E. H., 1930. Pre-Cretaceous rocks in wells of the Gulf Coastal Plain south of the Ouachita Mountains. 15th Ann. Meeting, Amer. Assoc. Petr. Geol., program, p. 5. Sellards, E. H., 1929. Underground position of the Pre-Cambrian and other metamorphic rocks in Texas. Mimeogr. circ., 7 pp., Austin.

western shores of Llanoria, and into this the Bend and later deposits were dumped. Without later complications one might expect these sediments to be thicker to the east, approaching their source. But instead, they are absent in central Bell County, and the basement complex consists of rocks metamorphosed by strong mountain-making forces.

This accords with the widespread behavior of geosynclines after loading with accumulated sediments. As in the Appalachian, the Californian, the Andean, the Himalayan and other thick sedimentary accumulations, the geosyncline is upheaved and mountainous structures emerge onto dry land. These are deformed by folding, faulting and thrusting, suffer metamorphism, and finally are planed down by erosion. This leaves a reduced, metamorphosed and structurally complex coastal land, which becomes submerged beneath a succeeding marine transgression. The facts in Bell County accord with this interpretation of the sediments as related to the history of Llanoria. The extent of this folded and metamorphosed belt in central Texas is unknown; it possibly extends at least from the region of San Antonio northwards to about Hillsboro and thence perhaps turns somewhat eastward to parallel the Ouachita mountain front or connect with the western part of the East Texas (or Fort Worth) geosyncline.[10a]

Much new work is required to unravel which rocks are part of the old land mass, and which the metamorphic products of the derived and deformed sediments in the bordering geosyncline. Apparently the phyllites and other strongly metamorphosed rocks in the deep wells in Caldwell and Falls counties[11] belong to the main body of Llanoria. Rocks underlying Terrell and Val Verde counties are of still disputed age, as are also some rocks in the Red River counties of Texas.

Lithology of Group I: The wells near the Kolls tract about 2½ miles northwest of Belton (Kolls Nos. 1–4; Hair 1)

[10a]Mineral Wells geosyncline of Plummer and Moore, 1920.

[11]In Caldwell County, the Tiller No. 2, Kelley No. 1, and Tabor No. 8. There are black true schists, like the Packsaddle Schist, in Tabor 2 at 6696 feet; green phyllites in Kelley 1 at 7240 feet; red phyllites close under the base of the Comanchean, in Kelley 1 at 4737 feet, and in a well in Falls County, Pucek No. 1, at 3569–3581 feet. At these localities metamorphosed rocks directly underlie the Comanchean.

so far as records show, had entirely rocks of Group I below the Comanchean. In the D. W. Hair No. 1, the base of the Comanchean was found at about 1157 feet. Below that depth mostly indurated black shales and quartzites were found. Some softer shale was reported near the bottom of the hole (above 2002 feet). The only samples saved, from 1132–1305 and from 1305–1310 feet, consist of quartzite and black indurated shale.

In the John Kolls No. 4 (Down, Perry and Hughes) the base of the Comanchean is at 1194 feet, and this well seems practically identical with the last. The log gives 1194–1445 T. D., as mostly alternating "black shale" and "*very hard* grayish-blue sand rock," *i.e.*, the black shale-quartzite series (Group I). The quartzite aggregates 179 feet in thickness, in beds averaging 22 feet thick; the indurated shale aggregates 72 feet thick, in beds of mostly 2 or 3 feet thickness but averaging 12 feet thick. This strikingly indicates the marginal or at least near-shore facies of those sediments, and suggests a situation resembling the gradation from the Arbuckle facies to the more eastern and nearer shore Ouachita facies in the Oklahoma Paleozoic.

The Stanfield well near Bland is reported to have struck below 1200 feet "hard rock" verbally described by those who saw both, as "exactly like" the hard rock in the Hair well (*i.e.*, quartzites). The situation in the Kolls Petoskey well is not quite clear because the "shale, dark gray, non-calcareous, with a little sand" from 1170–1193; the "clear quartz and a little dark gray sandstone" from 1197; and the "clear quartz, and some dark gray non-calcareous shale" from 1198 feet are noted as having the "aspect of Pennsylvanian"; but because they are on the same tract as the wells mentioned above, these sediments likely belong to the black shale-quartzite series. In the Holcomb (Dog Ridge) well, the driller reported "alternating sandstone and shale" at 1257–1550; a sample from 1150 was described as follows:

Fine grained, in part green, in part purplish quartzite-sandstone, affected by many small irregular shearing planes.

These rocks are probably of the black shale-quartzite series. Dr. Sellards reports a sample of black shale at 1065–1105 feet.

The Winans and Forbes well had a typical series of the black shale-quartzite series, from the base of the Comanchean (789 or 821) to the bottom of the hole (1780 feet). The available material is as follows (cores indicated by asterisk):

Black indurated shale: 1260 (with a little quartzite, and considerable red sand and other caving); 1260–1282 (red sand caving); *1924; *1320; 1325 (?); 1390; 1445 (shale and quartzite); 1507 (shale and quartzite); 1580; *1587; 1630 (shale and quartzite).

Quartzite: 1286, *1367, *1406 (quartzite and shale); *1500; *1512; 1545, 1550, 1655–1665 (quartzite and shale); *1680; *1745.

Light red, semi-friable sandstone: *1309. This last sample is interesting as showing interbedding of softer material in the metamorphic series. Likewise the Holcomb well showed some slight greens and reds in Group I.

Fossils from Group I: Schist-like shale with veins and slickensides in same sample with "greenish sandstone" and "limestone" from Bell-Williams, Warrick No. 1 at 1190–1255 feet, is reported as containing "many indistinct organic fragments." In Bacon No. 1 at 1100–1110 feet there is reported "very black slaty shale of fine texture. In thin section a minute fragment of coaly material, apparently a leaf, was seen. In closed tube, bituminous fumes sufficient to sustain a flame and fumes of sulphur and ammonia are given off." In Kolls, Down, Perry and Hughes No. 1 at 1400 feet, a sponge spicule was seen.

Fossils from Group II: From Bailey No. 1, there are several records of fossils or of structures suggesting organic origin:

2630–2640: "Tenticular minute bodies."
2640–2655: Sponge spicules. Spherical spinous bodies, 0.3 mm. diameter and less; one has 50 short spines on outside; several are flattened.

2655–2675: Outlines, doubtful. Round, slightly oblong, clear bodies, ⅛ mm. in diameter.
2740: Round clear bodies.
2850: Round or oval bodies.

Fossils from Groups V–VI: From Bailey No. 1 the following are reported:

3515–3540: In chert, a "large number of the circular, clear bodies of Radiolaria."
3540–3545: Fragments suggestive of organic origin.
3605–3615: Slender and crescentic bodies, possibly organic.
3640–3650: Radiolaria(?); other organic fragments.
3645–3650: Structures resembling Radiolaria.
3660–3672: Structures apparently Radiolaria.

The following organic remains are recorded from Slayden No. 2:

850: Spherical, reticular, spinose structures, "probably Radiolaria." These are in a "hard greenish slate"; green and red "slates" seem to occur together in these samples.
940: Red slate; many sponge spicules; a few Radiolaria.
945: Radiolaria in "both the red and gray rocks." In the Bailey well the radiolaria-bearing rocks are mostly gray.
950: Radiolaria and oval bodies in both greenish chert and clear crystalline flint.

CRETACEOUS

The Texas Cretaceous is divided into two series: Comanchean (Lower Cretaceous) and Gulf (Upper Cretaceous). In Bell County the Cretaceous formations, with their surface thicknesses and their subsurface thicknesses from the most reliable wells are as follows:

Formation:	Range in Wells Feet	Surface Thickness Feet	Lithologic Character
Gulf series:			
Taylor (Kta)	625+	800+	Limy marl; chalk lenses, sand.
Austin (Kau)	550–600	500?	Chalky limestone; chalk marl.
Eagle Ford (Kef)	133–172	105	Black shale; limestone flags.
Comanche series:			
Buda (Kbu)	0– 2	0–5	Shelly limestone.
Del Rio (Kdr)	105–114	80	Clay.
Georgetown (Kgt)	100?	100	Limestone and marl.
Edwards (Ked)	55	50	Limestone.
Comanche Peak (Kcp)	100	100	Nodular limestone.
Walnut (Kwa)	80–170?	150	Marl and marly limestone.
Glen Rose (Kgr)	600	?	Limestone and marl.
Travis Peak (Ktp)	175–281	no exp.	Sand, sandstone, clay.

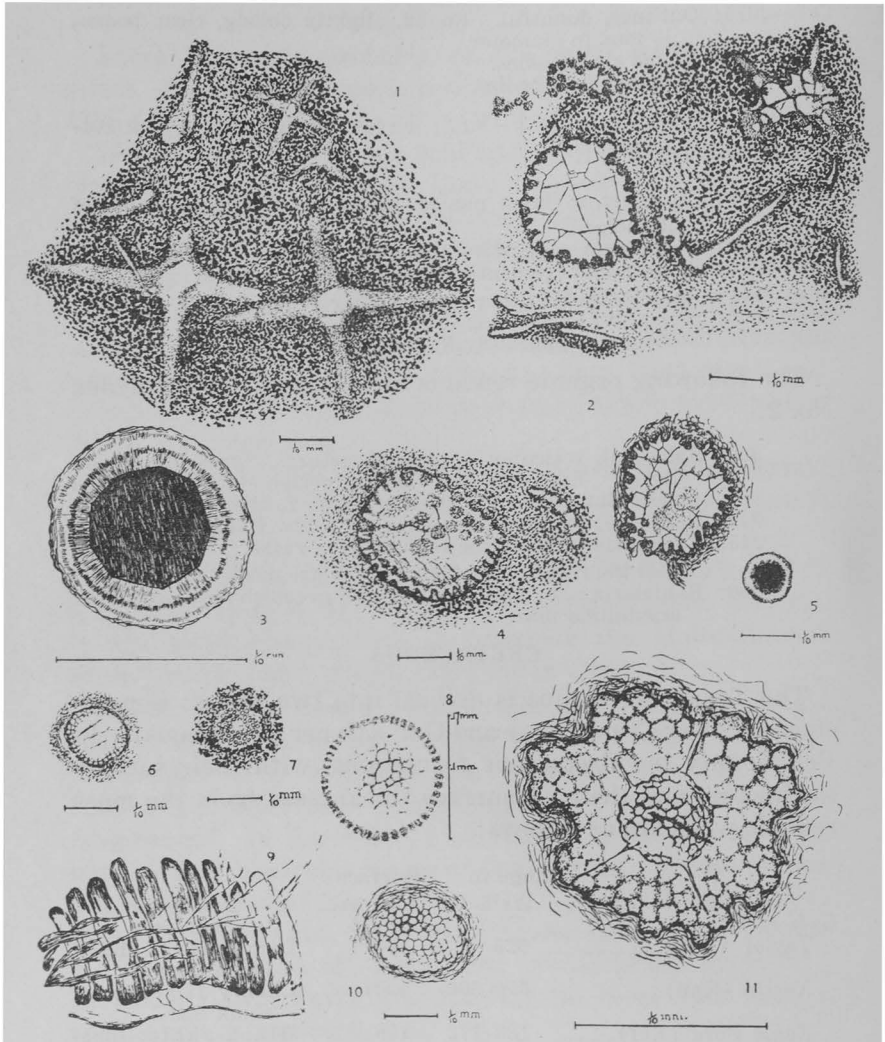

Fig. 1. Microscopic bodies found in pre-Comanchean rocks in Bell County. Figs. 1, 4 Slayden No. 2, at 940 feet; Figs. 2, 6–7 Slayden No. 2 at 945 feet; Figs. 8–11 Slayden No. 2 at 950 feet; Figs. 3–5 Noah Bailey No. 1 at 3,640–3,650 feet. No. 8 drawn by Helen Jeanne Plummer; others by Hortense T. Winton.

The upper portion of the Glen Rose is the lowest outcropping formation in Bell County; the Taylor is the highest outcropping marine formation. In the following pages is a brief description of the lithologic character, the outcrop and the occurrence in wells, the thickness, and the fossils of these Cretaceous formations, in Bell County.[12]

COMANCHE SERIES (LOWER CRETACEOUS)

TRINITY DIVISION

TRAVIS PEAK FORMATION

The nearest Travis Peak outcrop, bordering the Paleozoic inlier at Lampasas, is only 15 miles west of the western edge of Bell County. In this area the basalmost Cretaceous sea encroached westwards over an irregularly eroded Paleozoic floor, in which there was a generally northeast-trending high in the vicinity of Lampasas; the Travis Peak deposits are

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[12]The following are most of the Cretaceous fossils described from Bell County:

Acanthoceras bellense Adkins 1928, Univ. Texas Bull. 2838, p. 245 (Eagle Ford).

Acanthoceras stephensoni Adkins 1928, same, p. 246 (Eagle Ford).

Eucalycoceras leonense Adkins 1928, same, p. 240 (Eagle Ford).

Mantelliceras sellardsi Adkins 1928, same, p. 239 (Eagle Ford).

Chondrodonta munsoni (Hill) 1893, Proc. Biol. Soc. Washington, VIII, 97–108 (Edwards).

Eoradiolites davidsoni (Hill) 1893, same (Edwards).

Exogyra aquila Goldfuss, C. A. White 1884, U.S. Geol. Surv., 4th Ann. Rept., 304, pl. LIII, figs. 1–2.

Exogyra walkeri C. A. White [= *americana* Marcou] 1878, 12th Ann. Rept., U.S. Geol. Geogr. Surv. Terr., 278, pl. I, figs. 1 a–b, White 1884, U.S. Geol. Surv., 4th Ann. Rept. 307, pl. LIV, figs. 1–2. *Exogyra walkeri* White 1879, 11th Ann. Rept., U.S. Geol. Geogr. Surv. Terr. for 1877, 278, pl. I, figs. 1 a–b (type locality: Salado). Horizon. Fort Worth-Denton.

Exogyra tigrina Stephenson 1929, Proc. U.S. Nat. Mus., 76, art. 15, pp. 1–6, pls. 1–3 (Austin chalk, near top).

Ostrea centerensis Stephenson 1929, same, p. 2 (upper Austin chalk, type locality Center School west of Sparks).

Ostrea diluviana C. A. White 1888, U. S. Geol. Surv., 4th Ann. Rept., 295, pl. XL, fig. 1; pl. XLI, figs. 1–2 (Austin chalk?).

Pachymya austinensis Shumard. White 1879, 11th Ann. Rept., U. S. Geol. Geogr. Surv. Terr., 298, pl. 5, figs. 7 a–b (Georgetown).

Thracia myaeformis White 1880, U.S. Nat. Mus., II, 297; White 1883, 12th Ann. Rept., U. S. Geol. Geogr. Surv. Terr. for 1878, 23, pl. 17, figs. 2 a–b.

Trapezium compactum (White) 1880, Proc. U.S. Nat. Mus., II, 297, White 1878, 12th Ann. Rept., 22, pl. 17, figs. 4 a–b (as *Pachymya*).

Macraster obesus Adkins, *Macraster pseudoelegans* Adkins, *Eoradiolites quadratus* Adkins, *Eoradiolites angustus* Adkins, *Praeradiolites edwardsensis* Adkins, Univ. Texas. Bull. 3001-D (1930).

thin on this high, and on passing either north or south of this region, the Travis Peak thickens and the Paleozoic-Travis Peak contact drops in elevation.[13]

The basal Cretaceous formation (called "Trinity formation" in the Burnet folio) consists near Nix, just west of Lampasas, of about 20–25 feet of basal conglomerate succeeded by 30 feet of packsand; this grades into the overlying more limy Glen Rose beds. Eastward through Lampasas and Bell County, the Travis Peak rapidly thickens. In wells near Copperas Cove it is about 150–200 feet thick. In the Thomas Young well five miles north of Killeen, it is supposedly about 161 feet thick. Its indicated thickness from logs is, in the Ferguson (Tennessee Valley) well 175 feet, in the John Kolls, Down Perry and Hughes well, 281 feet. In the Noah Bailey No. 1 well, there was possibly 278 feet of Travis Peak. Evidently the basal Cretaceous bed, a sedimentary unit of conglomerates, packsands and other detrital materials characteristic of the marginal facies, thickens somewhat in passing eastwards across Bell County. If the Trinity sea was transgressive northwards and westwards over the Paleozoic floor, this deposit is by no means contemporaneous throughout its extent, but consists of the marginal "ends" of successive offshore beds of several ages. This was long ago pointed out by Hill and by others. In the absence of reliable fossils and other criteria for zonation in this area, the correlation of the deposit over its surface and subsurface extent has not been worked out, and the Travis Peak will here be treated as an empirical lithologic unit.

Lithologic Character: The most detailed available Bell County logs for the lithology of the Travis Peak formation are the Noah Bailey No. 1, the Holcomb No. 1, the D. H. Hair No. 1, and the John Kolls No. 4, Down, Perry and Hughes. These all indicate that the central Bell County area is far enough seawards so that the 20–50-foot basal conglomerates of Taff's Twin Mountain, Dublin and Hickory Creek marginal sections have given place to fine gravel or even fine sands.

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[12]Taff, J. A., 1893. Geol. Surv. Texas, 3d Ann. Rept., pp. 329–330. Paige, Sidney, 1912, Llano-Burnet folio, p. 9.

The general features of the Travis Peak in central Bell County, from logs and samples, are as follows:

		Feet
7.	Sandy shales, blue and white; average, about	20
6.	Packsand, white; first Trinity water	20
5.	Shales and sandy shales, black or blue	105
4.	Packsand and sandstone, white; second Trinity water	15
3.	Shales or sandy shales, blue, some red	50
2.	Sandstone and packsand; third Trinity water	40
1.	Basal beds: packsand and lenses of sandstone, brown and gray; fine gravel; some shale, blue and red	35
	Total average	285

The basal beds of the Trinity in central Bell County are not conglomeratic, but consist principally of packsands, coarse sands, fine gravel, and clay. The following from the Bureau records, is a description of a sample of this material from Holcomb No. 1, Lewis Walker survey, 2 miles northwest of Belton, depth 1065–1105 feet:

Sand and fine gravel composed of grains of quartz (60%), chert (25%), and calcareous material (15%), both limestone and dolomite. The calcareous grains reach their maximum size as fine gravel (1 to 2 mm. diameter), which amounts to 50 per cent of the calcareous material; their color is white (granular and clear), reddish-maroon, and dark gray. The color of the quartz grains is white or clear, pink, salmon-pink, and (rarely) pale green. The chert is mostly black to dark gray and pearl gray. The percentages of the several grades of material are:

	Per Cent
Very fine sand	Trace
Fine sand	9.5
Medium sand	13.5
Coarse sand	30.8
Fine gravel	28.9
Gravel	17.0

In other wells, there are reported from the basalmost Travis Peak, clay or shale (blue, red); gumbo (yellow); limestone (yellow, gray); sandy lime; sandstone (white, gray, brown); sand (white, gray); gravel (size not stated); and an oil show (in Bailey No. 1, at 760 feet). No grains are recorded above about 2 mm. diameter, and the formation in

central Bell County appears to have been deposited sufficiently seawards to lack the strictly marginal character recorded for the Travis Peak at the outcrop in Burnet and Lampasas counties. However, in Bacon No. 1 well, a basal conglomerate is logged.

The Travis Peak, above the basal portion, consists in general of three sandstone or packsand members each bearing a Trinity water level, and each capped by a member composed of shales and sandy shales. The sands are mostly white or gray; they are not coarse grained. The shales are black, blue, or rarely red. A description in the Bureau records of a sand near the top of the Travis Peak, from the Burris No. 1, Merchant well, 12 miles southwest of Belton, depth 552 feet, is as follows:

A small amount of lime-cemented fine-grained sand; most of the sample is uncemented quartz sand containing some feldspar and a few fragments of black chert. Mechanical analysis of the uncemented grains:

Diameter of Grains, Millimeters	Per Cent of Sample
4 to 2	5
2 to 1	20
1 to 1/2	25
1/2 to 1/4	10
1/4 to 1/8	35
1/8 to 1/16	5

An approximate mineral analysis gives the following results for the sizes of grains indicated:

Material	Grains from 4 to 2 mm. diam. Per Cent	Grains from 2 to 1 mm. diam. Per Cent
Quartz	60	75
Feldspar	28	14
Pink quartz	6	6
Chert	6	1
Undetermined	0	4

Travis Peak Samples from Stanfield, Ludwick No. 1

Sandstone, light gray, medium to coarse grained, containing thin regular laminations of greenish clay and one thin layer of gravelly sand. One large fragment of greenish-gray shale is present. The sizes of the sand grains are as follows:

	Per Cent
2 to 1 mm.	5
1 to 1/2	10
1/2 to 1/4	40
1/4 to 1/8	40
1/8 and less	5

Nearly all of the sand grains are of clear quartz. Some grains of pink quartz and dark chert occur 785

Coarse white sand containing some calcareous material and a small amount of light greenish-gray clay, stated by driller to be 30 feet thick. Size of sand grains:

	Per Cent
2 to 1 mm.	1
1 to 1/2	20
1/2 to 1/4	45
1/4 to 1/8	33
1/8 to 1/16	1

Nearly all of the sand grains are of clear quartz. Some grains of dark chert and pinkish quartz occur 791

Gray sandy shale and some light gray coarse sand like that from 791 feet. A few fragments of light gray limestone occur. Several echinoid spines and plates are present 821

Travis Peak Samples from Slayden No. 2

Gray indurated silt, some limonitic material; some calcareous material (probably caving). The silt makes 90 per cent of sample; in section, is finely granular and contains some fine, angular sand grains. Ranges in color from greenish-gray to purplish-gray. Fossils: a few fragments of highly calcareous material; pelecypod shell fragments (probably caving) 695

Light greenish-gray shale with calcite veins and a small quantity (5 per cent or less) of iron-stained rock. Sections of the shale show considerable silt. No fossils found 710

Light to greenish and brownish-gray shale (60 per cent), and iron-stained shale (40 per cent), the latter giving a slightly pink color to the sample. The material is very slightly calcareous. In thin section, the gray shale contains much silt, and some fine, worn sand grains. In thin section, the iron-stained shale contains considerable, fine worn sand grains. No fossils seen 720

Light gray shale containing a slight quantity of calcareous material and a small quantity of iron-stained rock. Contains in thin section a few fine, worn sand grains. No fossils seen 760

Medium gray marly shale, containing small veins of calcareous material. In thin section, is finely granular and contains a considerable quantity of fine, angular sand grains. No fossils seen .. 811

Thickness: No wells in eastern Bell County except the Holland city water well and Hardy No. 2 seem to have reached the Travis Peak formation. The thicknesses in some wells in western Bell County are as follows:

Wells:	Depths	Thickness Feet
Bailey 1	520– 798	278
Young 1	600– 761	161
Ferguson 1	646– 789?	143?
Hair 1	870–1157	287
Kolls 4	905–1194	289
Holcomb 1	850–1107	257

It appears, from inadequate logs, that in an area in northwestern Bell County the Travis Peak is thin; near Belton it is more uniformly 257–289 feet thick.

GLEN ROSE FORMATION

Lithologic Character: Most of the Glen Rose in this region consists of "alternating beds" of thin to medium-bedded limestone and marl. On hillsides this alternation produces an obvious "stair-step" topography, consisting of well-bedded resistant limestones forming shelves which are separated by receding layers of soft marl. The only Glen Rose exposures in Bell County, along upper Cowhouse Creek and along Lampasas River above Youngsport, show this lithology and topography.

Underground, the formation shows several conspicuous features: *(a)* the middle of the formation is a thick body of rather solid limestone, with few breaks; *(b)* near the top are a few shale and other soft breaks; *(c)* near the base the formation is decidedly broken by soft strata; *(d)* rather uniformly there are two water horizons, the upper at a level about 130–175 feet below the top, the lower about 240 feet below the top, of the Glen Rose.

Outcrop: There are two areas of outcrop of the Glen Rose formation in Bell County: *(a)* in the valley of Cowhouse Creek north of Brookhaven, from the county line for a little over three miles downstream; and *(b)* a larger area in southwestern Bell County in the valley of Lampasas River, from

the Burnet County line downstream to Youngsport. Downstream and east of these outcrops the formation dips gulfward beneath the Walnut clays, and underlies the area eastwards at constantly increasing depths.

Probably as much as half the thickness of the Glen Rose outcrops in the Youngsport-Maxdale-Okalla area, but no attempt has been made to measure its thickness at the outcrop. In the Maxdale area, the alternating topography of the formation is prominent. A tall cliff on the south side of Lampasas River a mile south of west of Maxdale exposes thin-bedded limestones and considerable fossiliferous marls. The top of the Glen Rose is well exposed along Cowhouse Creek at Hawkins Crossing east of Brookhaven, where it is a massive to medium, well-bedded, fossiliferous limestone.

Fossils and Age: At the Bell County localities examined the fossils are mostly unsatisfactory casts of pelecypods and gastropods, and do not furnish favorable material for zonation. It has been suggested by Dr. Böse that the genera *Dufrenoya, Parahoplites* and *Douvilleiceras* found in the Glen Rose elsewhere place its age as Upper Aptian and Lower Albian.

Thickness: The most satisfactory thicknesses in the county are the following:

Well:	Depths	Thickness Feet
Bailey 1	20 (144?)– 520	500 (376?)
Ferguson 1	98– 646	548
Young 1	50– 600	550
Holcomb 1	235– 850	615
Kolls 4	280– 905	625
Hair 1	243– 870	627
Hardy 2	?1979–2808	829?
Holland city well	1248–1912	664 (or possibly 747)

The upper Glen Rose water stratum was found at about 132 feet below the top of the Glen Rose in the Hair well, at 145 feet in the Holcomb well, at 175 feet in the Kolls No. 4, and at Youngsport (near top of Glen Rose) Hill reports a water flow at 150–160 feet. The second prominent Glen Rose water level was found in the Hair well at 237+ feet below the top of the Glen Rose, in the Ferguson well at

242 feet, and in the Holcomb well at 245 feet. An oil show was found in the Holcomb well at 375 feet below the top of the Glen Rose.

PALUXY FORMATION (?)

At the Glen Rose-Walnut contacts examined, no indication of Paluxy sand was seen. Nor do the available well records indicate any sand stratum or water level at this contact. It is possible that the southward extension of the Paluxy sand is present in Bell County as a sandy lime or limestone, but indications to this effect were not discovered during the present survey.

FREDERICKSBURG DIVISION

The Fredericksburg division of the Comanchean in Bell County consists of three principal groups of rocks, which can be taken as formations if considered only locally, but if viewed regionally can equally well be regarded as facies. They are as follows:

		Approximate Thickness in Bell County: Feet	Prevailing Lithology:
3.	Edwards	55	Limestone.
2.	Comanche Peak	100	Nodular limestone.
1.	Walnut	80–170	Marl and marly limestone.

It is possible that the Glen Rose-Walnut contact is marked by a disconformity corresponding to the general position of the Paluxy sand, considered absent in Bell County. At least, at a locality about a mile northwest of Ivy Gap, at a level taken to be the top of the Glen Rose, the rock is perforated by innumerable vertical cavities like molluscan borings. These are each a centimeter or more in diameter, and are filled with chalky and marly material like that of the overlying formation. The evidence for unconformity at the top of the Fredericksburg division at the position of the Kiamichi clay, which is missing in Bell County, is given later in this paper.

Lampasas Cut Plain: Like other Cretaceous formations in Bell County, the rocks of the Fredericksburg division dip

gulfwards. The main body of the Edwards limestone, the relatively resistant caprock of this division, forms a rugged upland, the roughest and least accessible area in Bell County. Passing westward from this area the formations rise in altitude, to the west edge of the Edwards outcrop. This edge is a prominent west-facing escarpment, which follows the strike of the formations across Bell County and forms long interstream divides of through-flowing streams as prolongations of its main body. The Edwards caprock is underlain by softer Comanche Peak limestone, whose lesser resistance to weathering causes it to undermine the Edwards and to form steep slopes to the level of the underlying Walnut clay plain. This topography is the Lampasas Cut Plain of Dr. R. T. Hill. It thus consists of a dissected scarp and outliers, which are composed of a relatively resistant Edwards cap, steep slopes in their upper half, of less resistant Comanche Peak marly limestone, and bases and valley plains of soft Walnut clay. At the edges and on the updip ends of the interstream prolongations from the main body of the upland, small buttes have been cut off as Edwards outliers. Such outliers are Miller, Crossville, Manere, Cowan, Douglas, Long, Turnbow, Cave, Twin, Ray, Peacock, Horsethief, and Hog Mountains, and numerous unnamed buttes. The process of isolation by erosion is well shown at Comanche Gap, at Sugarloaf Gap, and in the outliers (Cedar Mountain) from Ivy Gap. Penrose makes a suggestion towards explaining the precise location of the outliers.[14]

"The hills on either side of the valley rise abruptly, often almost vertically from the valley for 100–200 feet above the level of the river, and run off on either side in broad flat plateaus. The horizontal stratification is seen on their slopes, and occasionally solitary peaks rise up in the river bottom showing the same structure, and [these] are all that is left of the old base-level plateau which once overlaid the present level of the river bottom. Such are Hog Mountain, Ray's Knob, Long Mountain, Cedar Knobs, and numerous other peaks. The reason that such knobs are left standing in an eroded valley—isolated, abrupt, and small in area—requires some other explanation than that they are simply the uneroded parts of the old plateau. This explanation is seen when one of these peaks is ascended. The top is seen to

[14]Manuscript field notes on two trips in Bell County; dated April 6, 1889.

be covered by a thick coat of flints, some imbedded in their original limestone and others loose but compacted together in a solid bed. These localities evidently represent spots in the old plateau where the flints have been more numerous than elsewhere, and as erosion progressed the limestone matrix was leached away and the flints concentrated, until a solid coating was formed which protected the underlying limestone, while the parts of the plateau where the flints were fewer were not thus shielded from the weather and were eroded. The remaining peaks and plateaus are the only evidence of the former existence of spots rich in flint."

Other writers have suggested a relation between remnental outcrops and synclines.

WALNUT FORMATION

Lithologic Character: On the outcrop in Bell County, the Walnut formation is typically a blue or blackish clay, limy marl or shelly marl, with subordinate amounts of shell agglomerate (mostly innumerable *Gryphea marcoui*), thin limestone seams, or beds of nodular chalky impure limestone in a clay or marl matrix and with the nodules generally only slightly compressed. No sharp boundary can be drawn between this formation or facies and the overlying Comanche Peak limestone. From Cooke County southwards on the outcrop, the *Gryphea marcoui* agglomerates are prominent and mappable, but this facies lenses out to the south of Bell County and disappears in central Williamson County south of Florence. It should be stated that the Walnut lithology in Bell County is that of the type locality, and so are the fossils.

Outcrop: The Walnut clay forms the lowland floor of the Lampasas Cut Plain in Bell County west of the Comanche Peak outcrop and the lower half of outliers and bounding scarps of the Cut Plain. In the two areas already mentioned erosion has stripped the Walnut and exposed the Glen Rose limestone. The Walnut forms the south slope of Cowhouse Creek Valley at and west of Brookhaven; the large valley of South Noland Creek, in which Nolanville and Killeen are located; and a smaller area bordering the Lampasas River Valley from the Williamson County line via Youngsport, eastwards to Bell Hollow. In wells the Walnut is very generally logged as blue, fossiliferous clay.

Fossils and Age: Fossils are abundant at most Walnut localities. They are mostly pelecypod and gastropod casts, ammonites, and echinoids. Of the ammonites, the most abundant and valuable for zonation are species of *Oxytropidoceras, Engonoceras* and *Metengonoceras.* Of the pelecypods, *Inoceramus* and some others have zonal value. *Exogyra texana* and *Gryphea marcoui,* commonly stated to be markers for the Walnut must be used with caution: the former ranges from Glen Rose to Kiamichi, the latter throughout the Fredericksburg division, and both are abundant in other soft layers than Walnut. The commonest Walnut gastropods are *Anchura* and *Tylostoma.* Common echinoids are *Heteraster, Hemiaster* and *Phymosoma.* Worms, bryozoa and fish vertebrae have been found in the Walnut.

A general section of the Walnut in western Bell County, from outcrops, is as follows:

		Feet
COMANCHE PEAK: Compressed nodular light grayish limestone.		
WALNUT:	(7) Rounded-oval nodules of soft marly limestone in matrix of dark gray limy marl; abundant fossils	15
(6)	Gray marl weathering whitish and yellowish, with thin marly limestone flags; abundant fossils: *Oxytropidoceras* n. sp., *Oxy. trinitense* (Gabb), *Oxy. chihuahuense* (Böse), *Engonoceras* several species, *Metengonoceras*	25
(5)	*Gryphea marcoui* shell agglomerate, cemented	5
(4)	Marl with thin limestone seams	25
(3)	Prominent limestone seam	1
(2)	Marl with thin limestone seams, about	70
(1)	Several thin limy seams with thin marl interbedding; *Metengonoceras* aff. *hilli* present, *Oxytropidoceras* rare or absent	25
GLEN ROSE limestone.		

The Walnut in the Holland city water well contains some streaks of well-rounded quartz pebbles. These records follow:

Quartz gravel, consisting of very rounded pink and white quartz pebbles up to ¼ inch in diameter. Water rose 700 feet above bottom of hole. This stratum is 50 feet below the top of the Walnut, at	1115–1120
Blue clay; rounded quartz pebbles; 89 feet below top of Walnut	1155
Another unlabeled sample; rounded quartz pebbles; probably	1115–1120

Walnut Fossils, Bell County

Engonoceras spp.
Engonoceras boehmi
Metengonoceras hilli
Oxytropidoceras acutocarinatum
Oxy. boesei
Oxy. chihuahuense
Oxy. trinitense
Oxy. sp.
Cardita posodae Böse
Corbis (Mutiella) *roblesi* Böse
Cyprimeria texana (Roemer)
Cyprimeria sp. (small)
Exogyra texana Roemer
Homomya ?bravoensis
—*?jurafacies*
—aff. *ligeriensis*
—*?solida*
Gryphea marcoui
Inoceramus aff. *concentricus*
Leptosolen??
Modiola stonewallensis Cragin
Pecten (Neithea) *irregularis*
—*occidentalis*
—sp. (no tertiaries)
Protocardia filosa
—*texana*
Pteria aff. *aguilerae*
—*pedernalis*
Pholadomya pedernalis
—*sancti-sabae*
Pecten (Chlamys) sp.
Remondia robbinsi
Pinna comancheana
—*?guadalupae* Böse
Tapes
Trapezium texanum (Cypricardia)
Trigonia emoryi Conrad
Anchura sp.
—*subfusiformis* (Shumard)
Lunatia pedernalis (Hill, not Roemer)
Turritella granulata var. *cenomanensis*
Turritella spp.
Tylostoma chihuahuense Böse
—*elevatum* (Shumard)
—*mutabile* Gabb
Phymosoma texanum
Tetragramma aff. *hilli*
Holectypus planatus
spp.
Heteraster adkinsi Lambert
—*bohmi* de Loriol
—*mexicanus* Böse
—*mexicanus* Cotteau
—aff. *obliquatus*
—*texanus* Roemer
—aff. *texasus* (D'Orbigny)
—spp.
Epiaster whitei Clark
Hemiaster comanchei Clark
Serpula spp.
bryozoa
fish vertebra

Thickness: In the tall cliffs bordering Cowhouse Creek east of Hawkins Crossing, the Walnut is about 165 feet thick. Its thickness in certain Bell County wells is as follows:

Wells:	Depths	Thickness Feet
J. T. Reed 1	810– 900?	90
Hair 1	150?– 243	97?
Holcomb 1	100– 235 (or 295?)	135?
Hardy 2	1839–1999	160
Kolls 4	110– 280	170
Holland city well	1066–1248	182
Bailey 1	6– 144[15]	144+
Winans & Forbes	0– 98[15]	98+
Thomas Young	0– 100[15]	100+

[15]Incomplete thickness; well starts in the Walnut.

The Walnut thickens somewhat in passing eastwards across Bell County. From north to south along the strike it thins rapidly southwards from Bell County. This thinning, with change of facies, is particularly noticeable in Williamson County. From the fact that farther south the member called Walnut differs markedly in fossils from the true Walnut (presence of *Loriolia, Porocystis,* abundant *Holectypus,* absence or great rarity of *Oxytropidoceras),* it may be that the Walnut lenses out south of Williamson County.

COMANCHE PEAK FORMATION

Lithologic Character: Most of this formation consists of chalky or firm limestone nodules imbedded in a subordinate amount of limy marl matrix; locally it is mainly marl with subordinate amounts of chalky nodules or thin limy seams. The compression of the nodules varies with the amount of marly matrix. Most of the Comanche Peak is not distinctly bedded; in this feature it differs from the overlying Edwards, from which it is clearly separated. The Comanche Peak facies grades basally into the Walnut, which is likewise poorly bedded, and lithologically differs principally by its greater proportion of marl. There are locally a few well-bedded, thin to medium limestone ledges in the Comanche Peak. In Bell County, this formation has a dull chalky texture, which distinguishes it from the more pure and crystalline Edwards of the reef facies.

Outcrop: The Comanche Peak outcrops almost exclusively in steep scarps beneath the Edwards resistant caprock and above the soft clay floors of the Walnut valleys in the Lampasas Cut Plain. At practically no place does it form uplands. It thus follows the valley of Owl Creek from Seattle to Leon River below Bland; the valley of Cowhouse Creek and Leon River downstream to opposite Dunn's Canyon; forms the floor and slopes of the large valley of South Noland Creek to within three miles of Belton; the valley of Lampasas River from the Lampasas County line near Ivy Gap (in outliers) and the Burnet County line south of Maxdale, downstream to Bell Hollow.

In wells, it is generally not distinguished from the Edwards, but is easily separated from the underlying Walnut clay.

Fossils and Age: Zonation of the Comanche Peak can likely be accomplished by using the species of *Oxytropidoceras* and *Engonoceras*. Other ammonites as *Dipoloceras* and *Hamites* are still too rarely found to be useful in zonation. The formation, especially in its more marly levels contains abundant fossils, ammonites, pelecypod and gastropod casts, echinoids, and a few other less common groups. The fauna has a considerable resemblance to that of the Walnut. The following is a partial list of Comanche Peak fossils in Bell and adjoining counties.

Comanche Peak Fossils

Oxytropidoceras acutocarinatum (Shumard)
Oxy. trinitense (Gabb)
Oxy. n. sp.
Corbis (Mutiella) *roblesi* Böse
Engonoceras spp.
Cyprimeria texana (Roemer)
Cardita posodae Böse
Cardium subcongestum Böse
Homomya aff. *ligeriensis*
Inoceramus aff. *concentricus*
Pecten occidentalis Conrad
Pinna guadalupae Böse
Protocardia texana (Conrad)
Pteria pedernalis (Roemer)
Protocardia filosa (Conrad)
Tapes whitei Böse
Trigonia emoryi Conrad
Anchura subfusiformis (Shumard)
Anchura kiowana Cragin
Anchura sp. indet.
Turritella aff. *granulata* var. *cenomanensis*
Heteraster adkinsi Lambert (typical)
Heteraster spp.

EDWARDS FORMATION

Lithologic Character: The type locality of the Edwards formation of Hill was placed on the Edwards Plateau.[16] In Bell County the Edwards may generally be distinguished from the underlying Comanche Peak facies by having *(a)* persistent strata of limestone, medium to massive in thickness, instead of chalky limestone nodules in a subordinate amount of clay or marl matrix; *(b)* flint, in nodules and in

[16]The formation, earlier named Barton Creek limestone by Hill, was in 1897 called Edwards. By implication the type locality may be considered the Canyons of the Nueces, Edwards County, Texas (Hill and Vaughan, 1897, U.S. Geol. Surv., 18th Ann. Rept., pt. 2, p. 234). Hill and Vaughan 1898, U.S. Geol. Surv., Folio 42 (Nueces).

thin strata; *(c)* rudistids and caprinids; *(d)* a few other zone fossils: *Chondrodonta munsoni, Phacoides acute-lineolatus, Cladophyllia furcifera* and other fossils described by F. Roemer 1888 and by C. A. White; *(e)* and by several other kinds of rock: a nearly pure, organic, fragmental or detrital, white or gray coquina-like limestone composed mainly of comminuted shell fragments; pulverulent layers of finely divided, nearly pure calcium carbonate, produced by intraformational solution and redisposition, and associated with it, disintegrated remains of "honey-comb" limestone from which much of the lime has been dissolved; miliolid limestones; some platy to marly, sandy limestone, and sandy, limy clay, both finely laminated; some silty layers, possibly in part magnesian; rudistid and caprinid shell agglomerates, both compact and disintegrated.

Even in Bell County where the Edwards is thin, there are several phases of lithology. Three of these are especially common. There is a dense, ringing, fine-grained, medium to thin-bedded, light brownish or light salmon-colored limestone, which is sparse in fossils except that it contains numerous small imbedded fossils visible on fracture as cross-sections. This rock is mostly non-siliceous, but locally contains flints. It has a prominent conchoidal fracture. In proximity to this limestone, softer layers contain abundant rudistids. A second prominent lithologic type is a shell coquina, of rudistids, caprinids, pelecypods, gastropods, corals and other fossils cemented into a porous or cavernous mass of shell agglomerate and debris. This rock is a part of the rudistid reef facies. At some localities the rock is entirely calcareous; at others the fossils are partially silicified and the matrix only slightly so. Upon weathering the fossils become disengaged. This rock generally bears considerable iron oxids, and weathers to a dark red color. A third type, excellently exposed at the Santa Fe quarry three miles northwest of Belton, is a coquina of comminuted shell fragments (with some entire shells) of the rudistid reef facies. It is a white or light bluish-gray, entirely crystalline, soft, calcareous deposit, with a composition of 3 per cent or less of silica and the rest practically pure

calcium carbonate. The prominent fossils are rudistids *(Eoradiolites* and others) caprinids, corals, gastropods, pelecypods, echinoids, bryozoa, worms and other groups.

The top of the Edwards in Bell County is marked by well-bedded, thin, hard limestone, but beneath the top are some layers of softer, marly or nodular limestone with abundant rudistids. These soft "breaks" correspond in stratigraphic position to the "adobe" at the top of the Edwards at Luling and elsewhere in the coastal plain oilfields. The Edwards is plainly distinguishable from the unconformably overlying Duck Creek limestone by lithology and by fossils. At the base of the Edwards is a widespread, soft, siltstone layer, weathering yellow, locally marked by a peculiar group of caprinids, generally recognized in drilling, and a widespread water horizon of small capacity.

Outcrop: The Edwards outcrops as an irregular strip in the west-central part of Bell County. North of Lampasas River it occurs as the hard cap of long interstream divides, and on these the maximum outcrop width is 15 miles. South of Lampasas River the Edwards limestone forms a strip of very rugged country with a width of from 3 to 8, average 5, miles. In the Walnut plain west of the main outcrop are numerous scattered outliers with cappings of Edwards.

On the Coryell-Bell county line the Edwards occupies an eleven-mile strip from the cliffs on the east bank of Leon River southwest to the valley of Cowhouse Creek north of Brookhaven. The southern boundary of this outcrop follows the uplands bordering the valley of Cowhouse Creek downstream to Leon River, thence down that river through Tennessee Valley, to a point about 3 miles north of Belton. A second interstream area of highland divide capped by Edwards lies between the Cowhouse Creek-Leon River drainage to the north and the South Noland Creek drainage to the south. Along the broad valley of South Noland Creek runs the Santa Fe Railway (San Angelo branch), and in it are located the towns of Nolanville and Killeen. Between this valley and the Lampasas River Valley is a long narrow divide capped by Edwards.

South of Lampasas River the Edwards outcrop is a southwardly widening strip of rocky upland, the most rugged area in the county. This area is bounded to the west by a prominent cuesta face, overlooking the westward extent of Walnut lowlands of the Lampasas Cut Plain. The area dips eastward and is overlain by the rolling, mainly untimbered uplands of the Grand Prairie. It contains some inliers of lower formations, mainly Comanche Peak, in deeper stream valleys heading at the western edge of the Edwards outcrop, where steeper headwater gradients have cut through the Edwards cap.

Numerous prominent and picturesque outliers in the Lampasas Cut Plain near the western border of the Edwards give to the landscapes of western Bell County a distinctive appearance. On passing westwards from the west edge of the Grand Prairie, the east-dipping formations (Walnut, Comanche Peak, Edwards) whose dissection produces the characteristic topography of the Lampasas Cut Plain rise in elevation, and at the western ends and on the edges of the interstream divides small buttes (outliers) have been cut off from the main body of Edwards by erosion, and stand isolated in the Walnut plain. They are capped by harder and more resistant Edwards limestone, the upper half of their slopes consists of the somewhat less resistant Comanche Peak marly limestone, and the lower half of their slopes and the surrounding valleys consist of the soft marls and shell agglomerates of the Walnut.

Particularly good, or nearly complete, exposures of Edwards occur at points on the north side of Cowhouse Creek a mile east of Hawkins Crossing; one-half mile north of Sparta; just east of Chalk Bluff store, 3 miles east of Nolanville; on the Salado-Spring Valley road, 3 miles southwest of Salado at the point where the road leaves the Washita uplands and descends into the creek valley.

The Edwards resists erosion more strongly than do adjacent formations, and thus holds up topography. In the main area of the Lampasas Cut Plain it therefore caps divides and outliers. At the eastern edge of the Cut Plain, where the formations dip eastwards beneath the higher beds

of the Grand Prairie, it forms a broad, slightly rolling upland strip, east dipping, bounded on the west by a prominent west-facing irregular cuesta face, and with its surface topography predominantly controlled by long sub-parallel dip-slope streams. Of these the through-going ones, like Lampasas and Leon Rivers, cut deep down-stream reëntrants into this upland. But many shorter creeks head near the western border of the Edwards, and may be called consequent. In southern Bell County these various dip creeks are gathered into Salado Creek, a stream which flows almost in the strike and has its course located down the dip near the eastern edge of the Edwards outcrop and just beneath the inner border of Washita prairies. Lampasas River in part occupies a similar position in the soft Walnut plain to the west of the Edwards upland.

The detailed erosional features of Edwards limestone are numerous and varied. In general it follows the behavior of a relatively pure limestone in a fairly humid climate: its corrosional effects include karrenfelder, schratten weathering, a slight development of etched potholes, honeycomb rock, and pulverulent layers. Disintegration and internal solution from contained ground water with consequent liberation of inclusions, coquina and fossils are striking effects, which differ from those commonly seen on the Edwards Plateau and in the arid West.

Thickness: In Bell County the total Fredericksburg division is about 230 feet thick, of which the Edwards facies takes up about 50 feet. Farther south the division thickens, and the Edwards facies occupies most of the column.

Fossils and Age: Two paleontologic zones are provisionally distinguished in the small thickness of Edwards in Bell County:

b. Zone of *Eoradiolites davidsoni* (Hill), occupying about the upper 40 feet of the Edwards as here developed.

a. Zone of *Caprinula* n. sp., occupying the bottom 10 feet.

Zone of Eoradiolites davidsoni: Most of the limestone strata in this upper 40 feet of the Edwards in Bell County contain rudistids of various genera. Probably a smaller

component in various strata is devoid of rudistids, but consists of the several types of lithology which are generally associated with reef formations. In addition the rudistids are not uniformly present everywhere, but are "spotty." Rudistid limestones begin near the top of the Edwards, just below the gastropod ledge which, locally near Belton, composes the topmost stratum, and extend down as far as the Santa Fe quarry about 3 miles west of Belton. Good localities are Nolan Creek at and southeast of Belton, Leon River east of Belton, and Cedar Creek at Temple-Moffat road crossing; Dr. R. T. Hill verbally reports the level at Salado Creek near Salado. The type locality of *Eoradiolites davidsoni* and of *Chondrodonta munsoni* is in Leon River southeast of Belton.[17]

Some fossils found in this zone in Bell County are:[17a]

Eoradiolites davidsoni (Hill)
Eoradiolites quadratus Adkins
Eoradiolites angustus Adkins
Praeradiolites edwardsensis Adkins
Bournonia (?) sp.
Toucasia texana (Roemer)
Toucasia patagiata (White)
Monopleura sp. indet.
Requienia sp. indet.
Simple coral
Chondrodonta munsoni (Hill)
Pecten duplicicosta Roemer
Lima sp.
Nerinea cultrispira Roemer
Nerinea aff. *incisa* Giebel
Phacoides acute-lineolatus (Roemer)
Cerithium sp.
Oxytropidoceras n. sp.
Goniopygus cfr. *zitteli* Clark

Zone of Caprinula n. sp.: This is a fine silty zone, weathering a light brown color, uniformly situated at the base of the reef facies and over the compressed-nodular Comanche Peak limestone in this county. It is at most places not over 10 feet thick. Well records indicate that down dip it is a widespread, weak water horizon.

In it have been found so far only several undetermined *Caprinula* or other caprinid genera. Just beneath it, and referable to the non-reef facies here placed in the Comanche

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[17]Hill, R. T., 1893. The paleontology of the Cretaceous formations of Texas; The invertebrate fossils of the Caprina limestone beds. Proc. Biol. Soc. Washington, VIII, 97–108, pls. XII–XIII.

[17a]Adkins, W. S., 1930. New rudistids from the Texas and Mexican Cretaceous, Univ. Texas Bull. 3001-D.

Peak, is an assemblage of echinoids, pelecypods and gastropod casts characteristic for that level.

FREDERICKSBURG-WASHITA CONTACT

In Bell County the Kiamichi member is absent at the outcrop, and so far as known, in wells also. Its position at the Edwards-Duck Creek contact is marked by an unconformity throughout Bell County. No distinct evidence of Kiamichi in central Texas south of Bell County has been published, and it is probably absent at the outcrop southwards from southern McLennan County, where it has a thickness of only a few feet.[18] It is reported to be present, but thin, in southeastern Coryell County near Whitson.

On Noland Creek and Leon River east of Belton, the top of the Edwards is marked by a persistent, evenly bedded stratum of limestone 1.7–2.3 feet thick (thinner to the west). This stratum has typical Edwards lithology of the dense, crystalline, light salmon-colored type, and is entirely unlike the marly nodular Duck Creek. Its fossils are not very diagnostic for age determination: it contains innumerable gastropod casts of several genera, *Turritella, Nerinea* and others. The top surface of this layer shows distinct evidences of unconformity. It is irregularly corroded and pitted, and locally is scoured out to a depth of a foot or so, and the basal Duck Creek rests with uneven nodular bedding upon this scoured surface, with individuals of *Hamites* and *Desmoceras* directly in contact with the top surface of the Edwards. This surface is pitted with borings (molluscan?), which contain filling from the upper formation. It is covered, at places sparsely, at other places with a tangled mat, of small annulated worm tubes. This gastropod ledge appears to be localized in the Belton region. At Cedar Creek in north-central Bell County, it is absent, and the Duck Creek locally overlaps several feet down onto the eroded Edwards. Downstream from Salado, the top of the Edwards is corroded and pitted and the contact with the Duck Creek apparently is concordant.

[18]Adkins, W. S., 1924. Univ. Texas Bull. 2340, pp. 40–43.

In Brushy Creek at Round Rock, in Williamson County, above the thin *Toucasia reef,* is about 5.5 feet of soft marly limestone with *Oxytropidoceras, Tylostoma,* echinoids and other Fredericksburg fossils. There is no fossil evidence that Kiamichi is represented in this rock, and it is to be considered as an interfingering of the ammonite facies of the Edwards into the rudistid facies (cp J. A. Taff, 1892, Geol. Surv. Texas, 3d Ann. Rept., p. 344).

WASHITA DIVISION

The Washita division of the Comanchean (Lower) Cretaceous consists of three formations:

		Thickness Feet	Prevailing Lithology:
3.	Buda	0– 5	Limestone, shell debris.
2.	Del Rio	105–147	Clay.
1.	Georgetown	100	Chalky or marly limestone, and marl.

In Bell County, the Washita division is marked by unconformities at its top and bottom.

GEORGETOWN FORMATION

In Bell County, the Georgetown formation consists of five members, of which the middle one (Denton) is mappable only as a line on the scale here used, and on the map may be regarded as located at the Fort Worth-Weno boundary. These members are:

		Approximate Thickness Feet	Prevailing Lithology:
5.	Main Street	20	Limestone.
4.	Weno	15	Nodular limestone.
3.	Denton	5	Shell marl.
2.	Fort Worth	25	Marly limestone.
1.	Duck Creek	25	Nodular limestone.

DUCK CREEK MEMBER

Lithologic Character: The Duck Creek is chalky, argillaceous, nodular limestone with subordinate amounts of very limy marl. Its fresh color is dark gray, bluish or more generally blackish, its weathered color whitish. There is roughly

an alternation of fairly well bedded more limy and more marly strata each not over 2 feet thick. The alternation is quite irregular. Some limy layers have reduced amounts of marl, and the limy nodules are compact and compressed. The formation is soft, forms mostly receding layers in cliffs, and on uplands outcrops as a narrow belt beneath the Fort Worth prairie.

Outcrop: In Bell County the Duck Creek outcrop is nowhere more than about 1½ miles broad, and it averages little more than ¼ mile. It is a softer and less resistant formation than the overlying Fort Worth, and consequently forms across Bell County a narrow strip lying at the west foot of the broader Fort Worth prairie. Even on updip interstream divides the narrow Duck Creek outcrop closely hugs the edge of the Fort Worth limestone uplands. Good Duck Creek exposures occur at the hard top of the Edwards in stream cuts, notably near Whitson; on Stampede Creek; Cedar Creek; Noland Creek and Leon River, east of Belton; Salado and Smith Creeks.

Fossils and Age: Duck Creek paleontology has been discussed in previous papers on the Texas Cretaceous,[19] and it would be repetition to enlarge upon its features as seen in Bell County. Here the zonation as seen in the northern Texas counties is greatly condensed, and the formation is thinned to about 25 feet. The *Hamites* and *Desmoceras* zones are one zone near Belton, and lie directly upon the Edwards; they contain a few *Elobiceras.* The *Elobiceras* and early Pervinquieran zones as seen near Fort Stockton are apparently missing from the succession. The zones of *Pervinquieria shumardi* and *P. kiliani* are condensed. The top zones as seen at Fort Worth are either absent, or have not yet been located. Much detailed zonal work remains to be done on the Duck Creek, as on other Washita formations.

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[19]Hill, R. T., 1901. U.S. Geol. Surv., 21st Ann. Rept., pt. 7, pp. 249, 258, Adkins, W. S., and Winton, W. M., 1920. Univ. Texas Bull. 1945, pp. 18-21; and several areal papers published by the Bureau of Economic Geology.

List of Duck Creek Fossils from Bell County

Elobiceras serratescens (Cragin)?
—spp.
Pervinquieria kiliani (Lasswitz)
—*nodosa* (Böse)
—*shumardi* (Marcou)
—n. spp. (several)
Desmoceras laevicaniculatum (Roemer)
—(?)*brazoense* (Shumard)
Hamites comanchensis A. & W.
—*fremonti* Marcou
—spp.
Prohysteroceras burckhardti (Böse)
—*whitei* (Böse)
—*austinense* (Roemer)
Puzosia (?) n. sp.

FORT WORTH MEMBER

Lithologic Character: This member is a chalky, argillaceous nodular limestone, blackish or bluish-gray on fresh exposure, whitish on prolonged exposure. It is harder than the Duck Creek, most of its layers project on cliff faces, and it forms an upland prairie bordered to the west by the narrow Duck Creek outcrop, and surmounted by the thin Denton shell marl band and over it the Weno.

Outcrop: Its outcrop is nowhere over two miles wide and averages about a half mile. It forms the west half of the narrow strike strip of Grand Prairie (Washita) upland in its reduced southern development as seen in central Texas. On highway No. 2B it occurs south of Salado and south of Belton.

Fossils and Age: Practical markers for locating the Fort Worth level are *Pervinquieria maxima, Macraster texanus* and *M. aguilerae,* and an abundance of *Exogyra americana.* The zonal value of other fossils, especially species of *Pervinquieria,* has not yet been worked out. A common Fort Worth ammonite is *Prohysteroceras austinense.*

List of Fort Worth Fossils in Bell County

Pervinquieria maxima (Lasswitz)
Pervinquieria kiliani (Lasswitz)
Prohysteroceras austinense (Lasswitz)

"Ptychoceras" n. sp. (large)
Hyphantoceras (?) n. sp.
Holaster simplex Shumard
Macraster texanus Roemer
Macraster aguilerae Böse
Macraster pseudoelegans Adkins
Macraster nodopyga Lambert
Exogyra americana Marcou
Gryphea washitaensis Hill
Alectryonia (Arctostrea) aff. *carinata* Lamarck

DENTON MEMBER

Lithologic Character: The Denton shell marl, about 5 feet thick in Bell County, is a convenient marker for locating the approximate middle of the Georgetown and thereby identifying the members. It is the only prominent *Gryphea* agglomerate in the Georgetown (there is a small one, readily recognizable, in the Weno). On fresh exposure the Denton is a bluish-gray very shelly calcareous marl; on prolonged exposure its surface is a weathered concentrate of shell fragments, mostly *Gryphea washitaensis.* It contains a few insignificant clayey limestone seams. The Denton is here mapped with the Fort Worth limestone.

Outcrop: This member is not mapped separately, and may be located at the Fort Worth-Weno contact on the geologic map. One of the best exposures for study is in the abandoned railroad cut south of Noland Creek about one mile southeast of the courthouse at Belton.

Fossils and Age: One of the best fossils for locating this level is *Pervinquiera* n. sp., to be illustrated and described later. Practically, in central Texas, the Denton is characterized by an abundance of *Gryphea washitaensis* (shell marls to the south, agglomerates farther north) and frequent *Alectryonia (Arctostrea) carinata.* A considerable fauna of other pelecypods and gastropods occurs. Echinoids of the genus *Macraster* are common in the Denton.

List of Fossils from Denton in Bell County

Cymatoceras texanum (Shumard)
Pervinquieria n. sp.
Pervinquieria spp.

Turrilites ? 2 n. spp.
Macraster pseudoelegans Adkins
Macraster texanus Roemer
Macraster aguilerae Böse
Rhabdocidaris n. sp.
"Vola" catherina Cragin
Gryphea washitaensis Hill
Alectryonia (Arctostrea) *carinata* (Lamarck)

WENO MEMBER

Lithologic Character: The thinned Weno in Bell County consists of fairly well bedded, argillaceous, nodular, gray limestone and limy marl. These two materials occur in irregularly alternate beds, and the whole member is softer than the overlying Main Street cap. So in cliffs the Weno forms a receding ledge, and on uplands it produces a sloping prairie. South of Belton on interstream divides the Weno underlies unusually large strips of upland, but elsewhere its outcrop averages less than one-half mile in width.

Outcrop: The narrow Weno outcrop enters Bell County at its north corner, passes through Whitehall, Cedar Creek church, west of Pepper Creek school, and in the lowland west of Midway church; it partially caps the divides between Belton and Lampasas River and between the river and Salado; south of Salado it forms a narrow lowland strip west of the Buda scarp.

Fossils and Age: The most practicable Weno markers in this region are *Pervinquieria wintoni* and an undescribed smooth, giant species of the echinoid genus *Macraster*. The member is fairly fossiliferous in Bell County.

List of Weno Fossils from Bell County

Pervinquieria wintoni
Pervinquieria aff. *wintoni*
Hamites spp.
Macraster obesus Adkins
Macraster wenoensis (Adkins)

MAIN STREET MEMBER

Lithologic Character: The Main Street member forms the hard cap of the Georgetown formation in this region. It is harder, more crystalline and less marly than other

members of the Georgetown. It consists of a reduced thickness of compressed, nodular, slightly argillaceous limestone, bluish interiorly and weathering white.

Outcrop: The Main Street outcrop, averaging less than a mile in width, enters the county at the north corner and bounds to the west the soft Del Rio plain which lies at the west foot of the Del Rio-Eagle Ford scarp. It passes south through Whitehall, Cedar Creek, Pepper Creek school, and is well exposed at the underpass of the Belton-Temple highway under the Santa Fe track, where *Turrilites brazoensis* and *Exogyra arietina* may be collected. It caps the divide between Belton and Lampasas River, and outcrops in the large "horseshoe bend" of that river. From near Jones Mill it passes south-southwest along Smith Creek and follows near Highway No. 2B to the county line south of Prairie Dell.

Fossils and Age: The most conspicuous markers for the Main Street member are *"Acanthoceras"* aff. *cunningtoni* Böse the large *Turrilites brazoensis* and *Exogyra arietina.* Certain species of *Pervinquieria* (aff. *wintoni* and others) will probably prove to be markers.

List of Main Street Fossils in Bell County

Turrilites brazoensis Shumard
"Acanthoceras" aff. *cunningtoni* Böse, Univ. Texas Bull. 2748, p. 201.
Stoliczkaia n. spp.
Pervinquieria aff. *wintoni* Adkins
"Hamites" aff. *angolaensis* Choffat
Kingena wacoensis (Roemer)
Exogyra arietina Roemer
Ostrea sp.
Alectryonia sp.
Gryphea mucronata Gabb

DEL RIO FORMATION

Lithologic Character: Most of the Del Rio is a plastic, slightly calcareous clay. Its base, however, contains a few layers of alternating marl and soft marly limestone strata which may be considered transitional to the underlying Georgetown limestone. The upper Del Rio contains a few platy, silty slabs. Thus three lithologic portions of the Del Rio may be distinguished:

		Feet
c.	Clay with platy siltstone layers	10
b.	Plastic greenish-gray clay, about	60
a.	Alternating marl and marly limestone, transitional to Georgetown limestone	5

The Del Rio lithology has been frequently described in the literature, and it is needless to repeat descriptive details. Much of the clay is gypsiferous, pyritic or hematic, and somewhat calcareous. In color it is dark blue when fresh, light gray when weathered. The pyrite hydrates and oxidizes to diffused iron streaks and stains. Pyritic fossils, abundant in McLennan County, become sparser to the south, and are present but not abundant in Bell County.[20]

Outcrop: This formation outcrops beneath a conspicuous narrow lowland which borders to the west the prominent west-facing Buda-Eagle Ford escarpment in central Bell County. North of Leon River this lowland averages a mile or so in width, but south of the river it is narrower. As would be expected from such a soft formation in this location, it forms the valleys of subsequent streams running in the strike of the formations, notably Pepper Creek and Smith Creek. At most places the formation is overgrown with vegetation; the best Del Rio exposures are in deep stream cuts, along Pepper Creek, and on Leon River, 2½ miles southeast of Belton.

Fossils and Age: For practical purposes, *Exogyra arietina* in abundance may be considered diagnostic of the lower two-thirds of the Del Rio in this area, and *Gryphea mucronata* in abundance diagnostic of the upper third. Certain ammonities are found: *Turrilites brazoensis* and two or three species of *Stolizkaia;* and among the pyritic dwarfs, *Submantelliceras brazoense,* and *S. wacoense, Baculites* cf. *comanchensis, Hamites* spp., *Scaphites bosquensis, Adkinsia* (several species), *Scaphites subevolutus, Turrilites bosquensis* and other species. The age of this fauna has been discussed by Böse. (Univ. Texas Bull. 2748).

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[20]Some species of Del Rio pyritic micromorphs are described in Böse, Univ. Texas Bull. 2748 (1928); in Adkins, Univ. Texas Bull. 1856 (1920); and Adkins, Univ. Texas Bull. 2838 (1928). For localities see: Adkins, Univ. Texas Bull. 2340 (1924), pp. 46-58.

List of Del Rio Fossils in Bell County

Cottreauites spp.
Scaphites subevolutus Böse
Scaphites bosquensis Böse
Adkinsia spp.
Helicoceras (?) n. sp.
Baculites sp.
Engonoceras spp.
Stoliczakaia sp.
Turrilites bosquensis Adkins
Hemiaster calvini Clark
Heteraster spp.
Exogyra arietina Roemer
Gryphea mucronata Gabb
Haplostiche texana (Conrad)

Thickness: The following are thicknesses from the most reliable wells:

		Feet
Edds 2	916– 995	79
Hardy 1	1348–1453	105
Holland city	810– 890?	80?
Reed 1	490– 565	75

BUDA FORMATION

Lithologic Character: In the Bell County region the Buda occurs in a special, marginal and organic facies not found elsewhere in central Texas. The sediments forming the existing outcrop were deposited not far from the original shore line, and as the following discussion shows, the position of the Buda in the stratigraphic column is at some places marked by an unconformity. At one locality in the unconformity there are rolled and decayed Buda boulders, evidently swept into this position from a nearby source. In Texas the Buda occurs in at least four facies: *(a)* a submarginal facies of crystalline limestone with shells, organic fragments, glauconite specks, red blotches, the typical "burnt limestone" phase so widespread in central Texas; *(b)* a rudistid facies, as near Sierra Blanca; *(c)* a "porcellanous" facies as at Chispa Summit and the Solitario and southwards into Coahuila; and *(d)* a marginal facies, as in McLennan and Bell counties where present at the outcrop. In some well cores to the east of the outcrop are conditions intermediate between *(a)* and *(d)*.

The marginal facies consists of an impure, discolored, fragmental, organic, coralliferous limestone, of small thickness. It contains quantities of shells and shell fragments, and at places resembles a coquina or a coquina detritus. There is

some clay and sand. Iron blotches and stains are common. The rock is porous, roughly nodular, and poorly bedded. It contains abundant stocks and heads of compound corals. Its fossils are poorly preserved, some of them perhaps reworked. It is locally missing, and where present probably is marked by an unconformity above, though this has not been proven.

Outcrop: The narrow ribbon-like outcrop of Buda in Bell County, nowhere over about one-tenth mile wide, lies high on the west facing Buda-Eagle Ford erosional escarpment, whose lower slope consists of Del Rio clay. In this county south of Pendleton the Buda practically caps the escarpment, and the thin overlying Eagle Ford recedes eastward. It should be stated that this is not the same topographic feature as the White Rock Escarpment of north-central Texas or the Bosque Escarpment in McLennan County. The White Rock Escarpment west of Dallas, west of Midlothian, east of Hillsboro, and west of Waco, is formed by the base of the Austin chalk capping the upper Eagle Ford. Up the east side of Bosque River, from which the Bosque Escarpment was named, the Austin recedes from the crest of the main scarp, which south of McGregor and Moody and as far south as Pendleton (where the Eagle Ford rapidly thins) is surmounted by a broad Eagle Ford upland, and the break of the escarpment consists of an Eagle Ford flag member cap surmounting Del Rio clay. Over this stretch the Buda is absent except near Pendleton. Southwards through Bell County the Eagle Ford has shrunk greatly in thickness and is too little resistant to form a prominent scarp. The Buda, a thin but unusually resistant limestone, forms the cap of the escarpment; where the Buda is absent, the scarp breaks and recedes eastward. South of Prairie Dell the Eagle Ford outcrop narrows and the Austin again approaches the edge of the principal west-facing escarpment, and its scarp-making effect overshadows that of the Buda. For clearness this escarpment controlled by the Buda in Bell County will be distinguished from the others mentioned as the "Buda Escarpment."

The peculiar intermittent outcrop of the Buda across McLennan and Bell counties will now be described. One of

the writers[21] in 1924 described a gap, extending along the outcrop from about the Hill-McLennan county line southwards to a point east of Salado, Bell County, an air-line distance of about 60 miles, in which the shale member at the base of the Eagle Ford formation directly and concordantly overlies the Del Rio clay except at Bosqueville, where other buried formation (thin Buda, thin Woodbine) emerge from beneath the overlap and locally occupy the interval between Del Rio and Eagle Ford. As explained below, four other such areas exist at the outcrop in Bell County. The outcrop thus consists of portions in which the Buda is alternately present and absent. These portions will be described in order, from north to south, across McLennan and Bell counties.

Contact in Hill and McLennan counties: Near Aquilla the Woodbine is only a few feet thick, but its limits have not been identified with certainty. Localities near the Hill-McLennan County line expose two thin chalky limestone ledges (containing *Stoliczkaia texana* Cragin, and other high Washita fossils) near the top of the Del Rio clay, a thin oyster agglomerate at its top, a concordant contact with the overlying beds, a thin sandy ledge or two like certain Woodbine (?) ledges near Aquilla, and above these, lustrous black shale. This black shale occurs also at the brick pit just north of the county line, on the Missouri, Kansas and Texas Railway, Rotan branch.

From the county line southwards to Bosqueville the lustrous black shale at the base of the Eagle Ford concordantly overlies the Del Rio clay. The contact is even and regular, and is generally marked by a thin oyster agglomerate which contains many selenite crystals.

The outcrop in Keas' branch at Bosqueville has already been described in detail.[22] At the top of the Del Rio clay at Bosqueville, there is a thin, soft, chalky limestone ledge pasted directly onto the bottom of the thin, hard Buda ledge,

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[21]Adkins, W. S., 1924. Geology and mineral resources of McLennan County. Univ. Texas Bull. 2340, pp. 52-67.

[22]Adkins 1924, Univ. Texas Bull. 2340, p. 59.

forming one stratum 2.5 feet thick. The softer bottom portion of this stratum is assigned to the Del Rio because it lacks diagnostic Buda fossils, and because both north and south of Bosqueville a ledge (or two) similar lithologically and paleontologically to this occurs near the top of the Del Rio but overlain by typical Del Rio clay. The hard Buda ledge here contains *Pecten roemeri* Hill and *Exyogra* n. sp., both apparently Buda markers, and *Gryphea mucronata* Gabb, *Protocardia* sp. and other Washita fossils; also, mixed alongside the Buda fossils and apparently with identical preservation two oysters similar to *Ostrea carica* Cragin and *Ostrea soleniscus* Meek, which in the Texas section are considered Woodbine markers. Both the *Pecten roemeri* and the oysters seem indigenous, which disposes of the idea that this is a Woodbine deposit with rolled Buda fossils; it is possible, but purely speculative, that the rock is younger than typical Buda, high enough in the succession to include forms which elsewhere occur also in the Woodbine. The Buda is concordantly overlain by about two feet of thinly bedded sandy clay and sandstone, locally cross-bedded, with concretions and the two oysters just mentioned; this is considered to be Woodbine. The interval up to the black shale at the base of the Eagle Ford is concealed. This exposure has been encircled by shallow water wells which reach Del Rio without intervening Buda or Woodbine, and it there appears to be a pre-Pleistocene outlier.

From Bosqueville southward to the McLennan-Bell county line the Del Rio is directly overlain at several localities by the Eagle Ford basal black shale, with a thin oyster agglomerate at the contact.

Contact in Bell County: The southernmost one of these localities (967), now slightly overwashed, is mentioned for contrast with the next-described locality.

Comanche-Upper Cretaceous contact, at point 1.7 miles south-southwest of Moody, and 0.25 mile south of McLennan-Bell county line (Loc. 967, Univ. Texas Bull. 2340, page 57).

	Feet
Eagle Ford:	
Lustrous black shale, some limestone flags	15+
Oyster agglomerate	0.2
Del Rio:	
Typical Del Rio clay: *Gryphea mucronata*	4

Only 0.3 mile south of the preceding locality and 0.55 mile south of the county line is a locality which shows unique Buda relations: in the unconformity between Del Rio clay and Eagle Ford basal shale there are scattered boulders of water-rolled, rotten and disintegrated Buda limestone imbedded in a gypsiferous clay together with rounded pebbles and Washita fossils (both water-rolled and indigenous?). In view of the occurrence of Buda *in situ* just south of this point and its total absence immediately to the north, the locality is considered to demonstrate the remnental eroded "feather-edge" of the Buda, broken up by wave action of the post-Buda sea. This locality is about 100 yards upstream from the small bridge at the road corner.

Comanche-Upper Cretaceous contact at road corner 0.55 mile south of McLennan-Bell county line, and 2 miles south-southwest of Moody.

	Feet
Eagle Ford:	
Black lustrous gypsiferous shale, rather purplish-gray when dry; basal 3 feet contains fossils as on Belton-Temple road *(vide infra)*; exposed	5+
Post-Buda Washita:	
Irregular nodular stratum, which consists of yellowish and reddish, very gypsiferous, iron-stained clay, with gypsum crystals, iron hydroxids, pebbles (quartz, limestone, phosphate), and many Buda limestone boulders, water-worn and partly disintegrated. Maximum thickness seen, 180 mm.	0.6
Del Rio:	
Light gray sandy clay, 300 mm.	1
Light yellowish-gray, platy, friable sandstone, 120 mm.	0.4
Typical Del Rio clay, exposed	2+

At a roadside waterfall on the Shine place one mile west-southwest of Pendleton, typical, slightly sandy Del Rio devoid of pebbles or other reworked material in its top is overlain, with a slightly uneven contact by about 1.8 feet of Buda, of a lithology typical for this region. The Buda contains *Pecten roemeri* Hill, *Exogyra* n. sp., *Gryphea mucronata* Gabb and other Buda or high Washita species. From

about the McLennan-Bell line southwards to near Old Howard school, an air line distance of 8.8 miles, the Buda forms an uninterrupted outcrop.

From near Old Howard school to a point east of Pepper Creek school there is a gap on the outcrop, badly concealed by overwash but devoid of Buda float, which suggests absence of Buda at the outcrop for this distance.

Near the Temple-Moffat roa d about 4 miles northwest of Temple and 1.5 miles east of Pepper Creek school there is a Buda outcrop about ¾ mile long. This Buda is about 4 feet thick, makes a roadside waterfall, has typical coarse clastic and brecciated texture, and contains fossils typical for the formation in this area: *Pecten roemeri* Hill, *Exogyra* n. sp., *Trigonia* cfr. *clavigera* Cragin, *Gryphea mucronata* Gabb, *Ostrea, Spondylus,* simple and compound corals.

The air-line distance from Pepper Creek school south to Leon River is 7 miles; in this strip the Del Rio is everywhere directly overlain by the basal black shale of the Eagle Ford, so far as can be judged by visible exposures and by the float. A good contact exposure lies just south of the Belton-Temple road.

Comanche-Upper Cretaceous contact just south of Belton-Temple road, 1.6 miles east-northeast of underpass of Santa Fe Railway, in a small, unnamed branch of Pepper Creek.

		Feet
Austin chalk:		
	Typical Austin chalky limestone, exposed up creek	5+
Eagle Ford:		
I.	Black shale and thin lime flags with bentonite seams in abandoned interurban cut	30
H.	Black lustrous shale, about	20
G.	Limestone flag member (*Acanthoceras* zone)	5
F.	Black lustrous shale, purplish when dry; fossils about	49
E.	Black lustrous gypsiferous shale, abundant euhedral selenite crystals; some fossils; 177 mm.	0.6
D.	Reworked zone: sandy carbonaceous, gypsiferous clay, with quartz, phosphate and other pebbles, fish remains, lignitized wood, rolled Del Rio fossils; 134 mm., of which the basal 45 mm. is especially carbonaceous and rich in phosphatic pebbles; contains *Gryphea mucronata Exogyra arietina (?),* phosphatized fossils	0.45

	feet
Del Rio:	
C. Typical Del Rio clay; *Pecten*, other fossils; 448 mm.	1.5
B. Del Rio soft clayey limestone; 97 mm.	0.3
A. Typical Del Rio clay; exposed	0.7
Typical Del Rio clay, exposed down stream, about	25

In both directions from this exposure the formations and the contact are obscured by overwash; Buda float is absent; and the Eagle Ford is visible mainly as slabs of limestone float, rich in ammonites.[23]

Next southwards, a Buda outlier appears near the south bank of Leon River, north of the Belton-Little River road, about 2.5 miles southeast of Belton. The thin Buda is here underlain by the complete Del Rio, and is overlain by perhaps the black basal Eagle Ford shale (E-F of preceding section, here overwashed) and certainly by the Eagle Ford limestone flags (G of preceding section).

Comanche-Upper Cretaceous contact near south bank of Leon River, north of the Holland-Little River road, 2.5 miles southeast of Belton.

Eagle Ford:	Feet
Limestone flags, with typical ammonite fauna; about	5
Black shale, about	10
Buda:	
Typical Buda limestone; *Pecten roemeri, Exogyra* n. sp., *Gryphea mucronata, Trigonia;* both contacts concealed; about	4
Del Rio:	
Typical Del Rio clay: *Gryphea mucronata* abundant in top; *Exogyra arietina* in basal and middle parts; pyritic micromorphs occasional; about	70
Main Street:	
At top, *transition zone* of alternating marl and marly limestone with numerous *Turrilites brazoensis;* lower portion less marly and with harder limestones; typical Main Street fossils; exposed	12

Southeastward from this locality the Buda outcrop and float are missing. So far as can be learned, the basal Eagle Ford shale directly overlies the Del Rio; apparently the Buda at the preceding locality is an outlier.

The contact is overwashed in the valleys of Leon and Lampasas rivers, and can next be seen just upstream from

[23]Listed and some of them described in Adkins, W. S., 1928, Handbook of Texas Cretaceous fossils. Univ. Texas Bull. 2838, esp. pp. 32-33, 238-248.

the iron bridge on the Sumners Mill road over Lampasas River, where it was necessary to dig pits to reveal the stratigraphic relations. Points were chosen where the interval between *situ* exposures of Austin chalk and Del Rio clay is a minimum, and where Buda and Eagle Ford float is reduced or absent. It seems probable that the reduced interval here observed is a result of faulting.

Pit A. Bluff on east bank of Lampasas River, beneath gravel pit, about ¼ mile southwest of Summers Mill road bridge, and 4¾ miles a little east of south of Belton.

	Feet
Austin chalk:	
Typical chalky limestone; *Inoceramus subquadratus* Schlüter *Inoceramus* cfr. *undabundus* Meek, *Gryphea aucella* Roemer; exposed	35
Eagle Ford:	
Yellowish clay with thin seams of bentonitic clay, sandstone, and sandy limestone; undetermined ammonites; about	3
Del Rio:	
Typical Del Rio clay; total thickness about	50
Main Street:	
Long bluff on east bank of river, below pits. Transition zone at top of Main Street; marl with thin seams of marly limestone, abundant *Turrilites brazoensis* Roemer, *Pecten;* rare *Stoliczkaia* n. sp., *Pervinquieria,* other fossils	6
Harder Main Street limestone; exposed, about	6

In this pit the stratigraphic interval between the top of the Del Rio clay and the base of the Austin chalk is 3 feet. This small interval is caused either by depositional overlap, or by faulting or slumping. The large amount of debris made it impossible to decide between these alternatives.

Pit B. About 100 yards northeast of Pit A.

	Feet
Austin chalk:	
Typical Austin chalky limestone, exposed	30+
Eagle Ford:	
A trace of reworked typical lustrous black shale	1—
Buda:	
(missing)	
Del Rio:	
Typical Del Rio clay; exposed	10

The large amount of striated aragonite at this locality suggests faulting. Near the south bank of Salado Creek between Jones Mill and the abandoned ruins of Ferguson's Mill, the

Comanche-Upper Cretaceous contact is concealed by a group of faults arranged *en échelon;* just south of Ferguson's Mill, in a small graben, the Main Street is faulted against Austin chalk. No Buda has been found in this region.

Main Body of Buda Outcrop: The northernmost outcrop of the main Buda mass known in Texas is at a point 3 miles east of Salado. From this point southwards to the Bell-Williamson county line, the Buda has a continuous outcrop, and in this strip the Buda is nowhere more than 5 feet thick. On the Salado-Belle Plains school road, 1.5 miles east-southeast of Salado, the Buda contains many large coral stocks and heads; this feature and the coarse, brecciated and conglomeratic texture of the Buda at this point suggest a near-shore environment, with clastic detritus and shallow-water life. Fossils present here are: compound corals (several forms), *Pecten roemeri, Gryphea mucronata, Trigonia,* cfr. *clavigera, Spondylus.* On the Belton-Georgetown road just south of Prairie Dell, the Buda is slightly thicker and less coraliferous. Thence southwards through Williamson County, its thickness slowly increases. So far as examined, it is everywhere underlain by Del Rio, and overlain by basal Eagle Ford black shale, followed by the middle limestone flags.

Stratigraphic Summary: The Del Rio in McLennan and Bell counties seems everywhere to have its full thickness, or at least to have the top zone (of abundant *Gryphea mucronata,* sparse *Exogyra arietina* and pyrite fossils) intact; hence the formation was not deeply ravined in this area. This is confirmed by the failure, so far, to find in the rolled zone at the base of the upper Cretaceous a single fossil indicative of any level lower than upper Del Rio.

The Buda where present, rests concordantly and possibly conformably on the Del Rio; at least no evidence of lack of conformity is known. The northern edge of the main mass of the Buda rock-sheet in central Texas disappears beneath the outcrop at a point 3 miles east of Salado and thence passes gulfwards underground, in a northeasterly direction across Falls and southern Limestone and McLennan counties. Interior to this there was (and is, at the outcrop and

underground parallel to the main mass) a shattered "feather-edge" of the mass, a few miles wide, which was so thin that during the interval from Buda times to basal Eagle Ford times, it was broken to pieces by subsequent erosion, thereby reworking part of it, removing part, and leaving some areas as outliers. The erosion was subsequent because of the outliers, which cannot be explained by non-deposition; it was *probably* submarine, not subaerial, because there appears to be no ravining of the underlying Del Rio at the "feather-edge" nor of the relatively film-like sheet of Buda, which extends for miles southwards. This post-Buda erosion occurred in late Washita times according to the apparently indigenous Grypheas and Exogyras found in the rolled zone alongside pebbles, boulders, reworked Del Rio fossils and patches of coarse detritus. This surface composed at places of intact Buda limestone, at places of rolled Buda boulders, and at most places of thin detritus (or none) on a Del Rio clay surface, was later covered by Woodbine from Bosqueville northwards and eastwards (?); south of Bosqueville no definite Woodbine is known. In Bell County the reworked surface was covered by the lustrous black shale at the base of the Eagle Ford formation (its age is discussed below). This deposit was covered by the middle Eagle Ford limestone flags (*Acanthoceras* beds), and then by the upper Eagle Ford black bentonite-bearing shales. Locally however, these divisions of the Eagle Ford seem to be largely missing, and the Austin is in contact by depositional overlap or by faulting, with the Del Rio, or at least there is only a small interval between them.

At the north boundary of Bell County the Eagle Ford is at least 100 feet thick, and outcrops as a prominent upland 5 miles wide. Only 5 miles farther south it has thinned to about 40 feet, and the resulting outcrop has narrowed to one-half mile, thus forming a large *V* whose apex is near Pendleton. Southwards through Bell, Williamson and Travis counties, this reduced thickness is maintained at most localities.

Unconformity in Wells: Some Bell County wells have records of pebbles which may be from the contact of the Upper Cretaceous and the Comanchean. The J. S. Darnall

well 4 miles east of Holland has a record at 1065 feet of "quartz pebbles, mostly pinkish in color, a few white; with these the proximal end of a sea urchin spine; stated to be from 1055–1075 feet." This well probably ended in the top of the Del Rio and these pebbles suggest the unconformable contact at the top of the Del Rio.

Another similar record, equally suggestive and equally unconclusive, is in the Edds No. 1 well, in which a granite pebble was reported at about 925? feet by Dr. E. H. Sellards:

> A granite water worn pebble about one inch in diameter is said to have been taken from this well from the base of the Eagle Ford. Proof that the pebble came from the well is not conclusive, although it was said to have come up in the bailer.

It is to be noted that typical Buda limestone is present in the nearby Edds 2, and it is possible from the conflicting oral records that Edds No. 1 penetrated the top of the Del Rio.

There was saved from the Holland city water well an unlabeled sample containing rounded quartz pebbles; this sample contained black Eagle Ford shale and some caving from the Austin chalk. It is possibly from the contact. (Other quartz pebble samples from this well are referable to the Walnut clay.)

Thickness of Buda: *(a)* McLennan County: at Bosqueville, 2 feet; elsewhere at outcrop, absent; Axtell well, 1610–1669 feet (part of this interval). *(b)* Bell County: at Bell-McLennan line, absent; 0.3 mile south of line, a discontinuous layer of small boulders; west of Pendleton, 1.8 feet; Pepper Creek, 4 feet; Belton-Temple road, absent; Leon River, 4 feet; thence to Kolls Store, absent; 3 miles east of Salado and thence southwards (main mass), 2 to 5 feet. Davis, Edds No. 2, one mile southeast of Heidenheimer, about 1 foot, at depth of 860 feet. R. R. Penn, Rufus Hardy No. 1, northeast of Rogers, (?) feet at depth 1348 feet.

Conditions of Deposition: Barrell's general term diastem was applied to minor breaks in sea or lake deposition when

wave base or currents will not permit of continued sedimentation.[24] Heim[25] has summarized, with numerous examples taken from the Cretaceous, a more detailed and useful terminology. It is likely that some kinds of submarine denudation apply to the formations here discussed.

GULF SERIES (UPPER CRETACEOUS)

EAGLE FORD FORMATION

Lithologic Character: The thinned Eagle Ford in central Bell County (south of Pendleton) consists of three thin members:

		Feet
c.	Lustrous black shales and scattered limestone flags	50
b.	Limestone flag member (*Acanthoceras* flags)	5+
a.	Black lustrous (some purplish) fossiliferous shales	50

Northwards from Pendleton to the McLennan County line the Eagle Ford outcrop rapidly widens in the form of a northwardly expanding *V*, and correspondingly the formation thickens. In this area it is similar to the section already described in McLennan County. In central Bell County the bulk of the formation is lustrous black shale, splinter shale, and pepper-and-salt shale, but the hard and resistant crystalline limestone flags of small thickness are topographically prominent. The base of the Eagle Ford contains reworked materials, as has been described. The shales are practically non-calcareous at most localities. The flags are coarsely crystalline, and contain inclusions of lignitized and carbonized wood, phosphate and other materials. The Eagle Ford shales cave badly in open holes.

Outcrop: At the McLennan County line the outcrop is 5 miles wide; from Pendleton southwards it averages about ¾ mile wide. It caps the Buda escarpment and, dipping, eastward, forms a gentle slope to the edge of the Austin chalk.

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[24]Schuchert, Charles, 1927. Unconformities as seen in disconformities and diastems. Am. Jour. Sci., XIII, 260-262. Barrell, Joseph, 1917. Rhythms and the measurements of geologic time. Bull. Geol. Soc. Amer., 28, 745-904.

[25]Heim, Arnold, 1925. Uber submarine Denudation und chemische Sedimente. Geol. Rundschau, Bd. XV, Heft I, 1-47.

Good exposures are few for the reason that the Buda scarp is a drainage divide; those streams heading near the crest and flowing east have cut shallowly into the Eagle Ford in their headwaters, and the short west-flowing laterals heading from the cuesta face have too little erosive force to cut deep exposures. The best exposures are either along through-flowing streams or on west-flowing laterals which head at breaks in the scarp, like certain branches of Pepper Creek.

Fossils and Age: The basal lustrous black shales, called by some writers Woodbine on considerations of lithology and stratigraphic position, contain fossils unlike any Woodbine species so far described from Texas; exact determination of the age of these basal shales awaits a closer study of the fossils. The *Acanthoceras* flags of the middle Eagle Ford, most richly fossiliferous in central Bell County, are of Upper Cenomanian age,[26] the Acanthoceratan division of Spath.[27] They contain numerous species of *Acanthoceras, Eucalycoceras, Metacalycoceras, Turrilites* and others distinctive of that age.[28] Among the turrilites recently discovered are forms comparable to the typical *T. costatus,* guide fossil of the Upper Cenomanian. The flags in Bell County are of Cenomanian age, the upper shales with bentonite are probably Turonian.

Fossils from Eagle Ford Formation in Bell County

Scaphites aff. *aequalis* Sowerby
Turrilites aff. *costatus* Sowerby
Turrilites aff. *wiesti* Sharpe
Turrilites aff. *hugardianus* D'Orbigny
Turrilites aff. *tuberculatus* Bosquet
Turrilites aff. *desnoyersi* D'Orbigny
Acanthoceras bellense Adkins
Acanthoceras lonsdalei Adkins
Acanthoceras stephensoni Adkins

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[26]Adkins, W. S., 1928. Handbook of Texas Cretaceous fossils. Univ. Texas Bull. 2838, pp. 28-30, 32-33.

[27]Spath, L. F., 1926. On the zones of the Cenomanian and the uppermost Albian. Proc. Geol. Assoc., XXXVII, 420-432, esp. p. 425.

[28]Compare: Reeside, John B., Jr., 1927. An *Acanthoceras rotomagense* fauna in the Cretaceous of the Western Interior. Jour. Wash. Acad. Sci., Vol. 17, no. 17, 453-454.

Acanthoceras aff. *cornutum* Kossmat
Acanthoceras aff. *cunningtoni* Sharpe (pl. XV, fig. 2)
Acanthoceras aff. *evolutum* Spath
Acanthoceras aff. *turneri* White
Acanthoceras aff. *discoidale* Stoliczka
Acanthoceras aff. *meridionale* var. *africana* Pervinquière
Acanthoceras aff. *confusum* Guéranger
Eucalycoceras leonense Adkins
Metacalycoceras 2 spp.
Mantelliceras sellardsi Adkins
Helicoceras (?) sp.
Unidentified ammonites
Metoicoceras spp.
Inoceramus spp.
Fish remains
Fossil wood

Thickness: The following are the supposed thicknesses of Eagle Ford in certain wells in eastern Bell County:

Wells:	Depths	Thickness Feet
Edds 2	756– 913	157
Reed 1	283– 416	133
Hardy 1	1176–1348	172
Hardy 2 (reported)	810– 980	170

The outcrop thickness between Belton and Temple is about 105 feet. The Eagle Ford thickens to the east, in part by intercalation of extra beds missing in the unconformities at the outcrop. At Mexia in Limestone County it has a reported thickness of 300–400 feet. The wells in eastern Bell County record almost entirely black shale, and the limestone flags if present were not logged.

AUSTIN FORMATION

Lithologic Character: The Austin chalk in Bell County consists of white, slightly argillaceous, chalky, fairly soft limestone, with subordinate amounts of softer chalky marl. It is at most levels well-bedded in thin to medium strata. Pyrite, in balls, tubes, crystals or disseminated, is common. Chert appears to be rare or missing. Faults and joints are widespread and conspicuous. Fossils are common at some levels.

Outcrop: The outcrop is rather uniform in width across Bell County. Near the Falls County line it is about 3 miles wide; near Temple about 4 miles wide; near Mount Vernon Church about 2 miles; south of Summers Mill about 2½ miles; at the Williamson County line about 4 miles wide; it thus averages about 3 miles wide. Good exposures of its basal contact are very rare. Its top, as seen at several localities, appears to grade into the overlying chalky marl provisionally referred to the Taylor.

The Austin-Taylor contact crosses the Falls-Bell county line on Deer Creek and passes nearly due south, making narrow downstream reëntrants along Big Elm, Pecan, Cottonwood and Little Elm creeks, and passing through Temple near the Santa Fe-Missouri, Kansas and Texas Railway crossing, passes southwards, keeping to the west of the latter railway. The formation underlies rolling uplands, many of them chalky white from absence of soil, and is best exposed in stream cuts. Good exposures are on Deer Creek, near Cottonwood School, in railway cuts 2 miles north of Temple and near Pendleton, east of Troy, in the ravines near Mount Vernon School, in the branches of Dorr's Creek west of Holland, and along creeks northwest of Bartlett. Some excellent exposures occur along Lampasas River and lower Salado Creek near Dulaney's Ford and Summers Mill.

The Austin chalk is locally affected by faults, notably north of Mount Vernon School, near Summers Mill, and on branches of upper Darr's Creek southwest of Holland. These are listed in the discussion of Structural Geology.

Base of Austin Chalk: In the K. H. Hill No. 1, Pure Oil Company core test on the west side of the "Knobs," 3 miles west-northwest of Rogers, the base of the chalk at 977 feet is marked by a zone of about 4 inches in thickness in which subrounded chunks of black Eagle Ford indurated shale and phosphatic particles, including phosphatized *Baculites,* are included in a gray-brown friable matrix of basal Austin chalk. The lowest 1½ inches includes pebbles up to 1¼ inches in diameter, and the remainder has particles of less than about ¼ inch in diameter. This contact is difficult to observe on the outcrop.

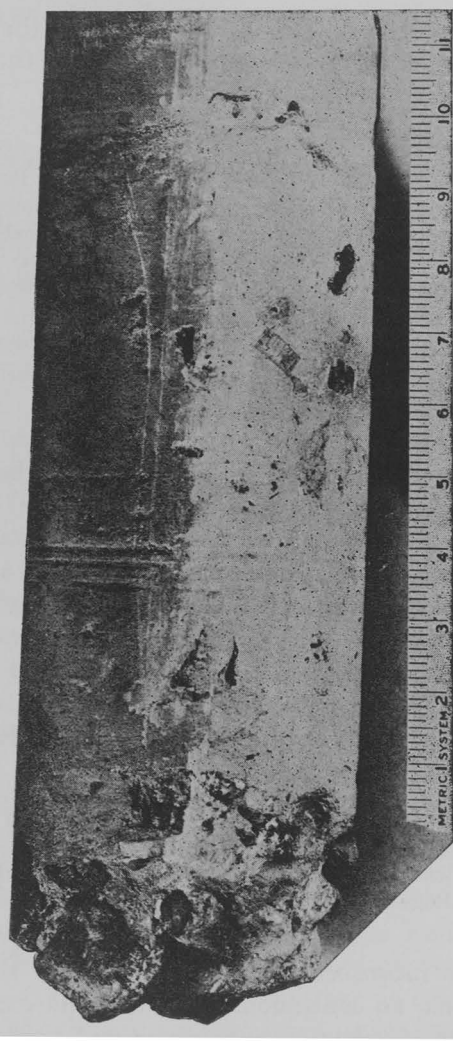

Fig. 2.—Basal contact of Austin chalk with inclusions of Eagle Ford black shale and phosphatized fossils; Pure Oil Company's core test (Hill No. 1) 3 miles west of Rogers, at 977 feet.

Thickness: The following are some chalk thicknesses from wells:

		Feet
K. H. Hill, Pure core test	373– 977	604
Edds 2	170– 736	566
Mosley 1	95– 600	505
Holland city water well	150– 625	475
Rufus Hardy 1	625–1175	550
Ancniec 1	560– 750?	190?
Spanhel 1	540– 735?	195?
Reed 1	0– 325	325+

Fossils and Age: No satisfactory zonation of the Austin chalk is yet available. The following are some of the fossils reported from it from Bell County.

Mortoniceras spp.
Parapuzosia 2 spp.
Phlycticrioceras n. sp.
Nautilus (Cymatoceras) aff. *elegans* Sowerby
Inoceramus subquadratus Schlüter
Inoceramus undulato-plicatus Roemer
Inoceramus (several species)
Exogyra aff. *ponderosa* Roemer
Exogyra tigrina Stephenson
Ostrea centerensis Stephenson
Gryphea aucella Roemer
Spondylus guadalupae Roemer
Pecten bensoni Kniker
Hemiaster texanus Roemer

TAYLOR FORMATION

Lithologic Character: The Taylor is the highest outcropping marine formation in the county. The outcrop covers about the eastern one-third of the county, is about 18 miles wide within the county, and probably involves a Taylor thickness of at least 800 feet. There is more Taylor east of Bell County on the outcrop. In Milam County, next east of Bell, the Taylor is reported to reach a thickness of 1150 feet underground.

In Bell County, the Taylor may somewhat arbitrarily be divided into five levels:

e. Chalk lens (position of Marlin chalk?)
d. Marl, east of Rogers
c. Rogers chalk lens (approximate position of Lott chalk)
b. Marl, west of Rogers
a. Chalk marl

Because of the inconsecutive outcrop, even in the most deeply cut streams, no continuous exposure and exact surface measurement of thicknesses exist. Good exposures of basal Taylor exist in the headwaters of Little Elm Creek near Little Flock Church and Oscar, east of Temple; in Cottonwood Creek; and along the branches of Darr's Creek west of Holland.

Basal Chalk Marl: This member forms an outcrop a mile or so wide just above the hard Austin chalk. It is seen to advantage and completely exposed on Darr's Creek, and both

upstream and downstream from Little Flock Church. In the Hill Pure Oil core test west of Rogers it is about 35 feet thick (338–373) but on the outcrop it appears to be thicker. Some of the large fossils are *Parapuzosia* sp., *Exogyra ponderosa* var., *Anomia* sp., *Ostrea* sp., *Hamulus onyx,* and *Hamulus* sp. aff. *jonahensis* Cragin. This member is softer than the Austin chalk and weathers accordingly; at several places strike streams bordering the eastern margin of the chalk run in it.

Lower Taylor Marl: This member forms a wide outcrop and is exposed as far east of Temple as "The Knobs," a striking line of hills in southeastern Bell County. It consists of typical Taylor calcareous marl, bluish-black on fresh exposure and weathering grayish-yellow. Its thickness is 350 feet or more; in the Hill Pure Oil core test the first 338 feet consists of this member. Some fossils are *Scaphites hippocrepis,* a genus like *Phlycticrioceras, Exogyra ponderosa, Inoceramus* spp., *Ostrea falcata, Ostrea plumosa, Anomia* sp., *Pycnodonta vesicularis* var., *Gryphea* aff. *aucella, Durania austinensis* (?), *Sauvagesia* sp.

Rogers Chalk Lens: The type locality of this member is taken as the several exposures on a small creek from about a mile to 1¼ miles south and a little west of Rogers. These banks are not more than 15 feet high and expose inconsecutively a chalk which is fairly persistent in southeastern Bell County. It occurs in the center and western parts of the H. G. Hendricks land about 2 to 2¼ miles southwest of Rogers and thence following the strike a little east of north, at disconnected outcrops almost to the Falls County line. Some of these exposures are indicated on the geologic map. This is a soft marly chalk, bluish-gray on original exposure, dull grayish-white upon exposure, with mostly poor, but locally platy, bedding and little clay or iron segregations. It contains *Exogyra ponderosa* var., *Pycnodonta vesicularis* var., *Anomia* and other fossils. It is probably less than 50 feet thick, but its exact thickness could not be measured on the outcrop. The E. Fisher well at Buckholts, western Milam County, has a record of the top of the "Pecan Gap chalk," which may be this chalk, at 424 feet and its base at

534 feet, but it is improbable that this refers solely to the chalk here called Rogers member, because it appears from the outcrop that there are still higher, and scattered, possibly lenticular, chalks in this area. Beneath the chalk a 16-foot sand is logged.

Upper Taylor Marl: This includes provisionally the remaining exposed Taylor formation in Bell County. This portion would reach more than 424 feet in thickness, the figure logged in the Fisher well, which is still west of the Navarro contact. It is therefore probable that there is at least 1000 feet of Taylor in this region. The upper marl contains some scattered chalks, notably in a creek on the H. Weigreffe land, Jos. Clark survey, in the northeast corner of Bell County; on the Louis Halzley survey just across the line in Falls County; in Milam County northwest of Buckholts on the south branch of Big Elm Creek and in wells on the J. H. Clark survey. Some of these higher chalks may be near or in the position of the Marlin chalk. Among these are chalk outcrops in North Elm Creek 1¼ miles west-northwest of the east corner of Bell County, and in South Elm Creek 1¾ miles south of Edgeworth.

Thickness: The following wells starting in the Taylor give, as incomplete thicknesses for the formation:

	Feet
Hill, Pure oil core test	373
Hardy 1	625
Hardy 2 (reported)	620
Ancniec 1	560(?)
Spanhel 1	540
Mosley 1	95(?)
Edds 2	170
Holland city water well	150

LATE CENOZOIC

REYNOSA FORMATION

The synonymy of the name "Reynosa" as applied to high inland gravel deposits often called Uvalde gravel is discussed by Deussen.[29] Flint gravel and cobbles, derived per-

[29]Deussen, Alexander, 1924. U.S. Geol. Surv., Prof. Paper 126, p. 105.

haps largely from the weathering of flint-bearing Fredericksburg limestones of the Edwards Plateau during the late Cenozoic, is a leading feature of the upstream phase of the Reynosa. Such flint gravels or veneers occur in Bell County between Bartlett and Holland, along the Santa Fe Railway from Temple southeast to Buckholts, and between the branches of Elm Creek in eastern Bell County. The elevation of Little River from the Milam County line upstream to the junction of Leon and Lampasas rivers is about 370–400 feet. The elevation of the Reynosa area north of Bartlett is 225 or more feet higher. The elevations of the deposits from Heidenheimer to Buckholts range from 150 to 240 feet above the river. At places there seems to be only a thin, loose veneer of flint pebbles and cobbles, and elsewhere there occurs a considerable thickness of pebbles loosely cemented with limy material. There is no record of Reynosa fossils in Bell County.

PLEISTOCENE TERRACES

Vertebrate fossils afford the primary evidence for age determination of the Pleistocene in Bell County. Those recorded by Dr. Hay follow:

Mammut americanum Kerr. *(a)* Lower right last molar; hills near Sparta; collections of Baylor University Museum. *(b)* Second true molar; J. B. Warner gravel pit, 1½ miles east of Belton, and about 100 feet above Leon River; collected by Miss Lula L. Taylor, Belton.

Elephas boreus ("primigenius"). Lower left antepenultimate milk molar; W. S. McGregor gravel pit, ½ mile north of Shallow Ford of Leon River, east of Belton.

Elephas imperator Leidy. *(a)* Upper left molar; found at Temple; Dr. Mark Francis. *(b)* Vertebrae; gravel pit half way between Belton and Temple [near Midway].

Elephas imperator Leidy, or *E. columbi* Falconer. Lower left hindmost molar; gravel pit half way between Belton and Temple.

Elephas columbi Falconer. Teeth; gravel pit half way between Belton and Temple[30]; collected by Mr. W. F. McGregor.

Equus semiplicatus Cope. Three teeth; same locality as last.[30]

Tapirus sp. indet. Three cervical vertebrae; same locality as last.[30]

[30]This locality is given (Hay 1924, Carnegie Inst. Publ. 322-A, p. 161) as a gravel pit halfway between Temple and Belton; (i.e., one of the Midway pits); but apparently the same fossils are recorded "at Temple" (p. 155) and "a mile north of Shallow Ford" of Leon River (p. 47).

Camelops macrocephalus Cope. Three cannon bones; same locality as last.[30]

Mylodon harlani Owen. Humerus; same locality as last.[30]

Testudo francisi Hay.[31] Great land tortoise; type locality; same as last.[30]

Hill[32] states that there are three terraces along Leon River between Belton and Temple.

The alluvial deposits of Noland River between Belton and Temple are exceedingly fine. On the east side of this stream there are three distinct alluvial plains above the present flood plain. The first of these is about 30 feet above the river and makes a well-defined second bottom, often 100 yards or more in width, composed of a light-colored calcareous marl. Still above this is a second bench, 20 feet in height, composed of the same material as the first terrace. Both of these are of the Onion Creek type. Over half a mile back from the river there is an upland plain, 150 feet above the stream, making the highest and oldest alluvial deposit, the Asylum terrace previously mentioned.

Hay[33] states that the Bell County fossils come from the lowest terrace. He says:

> The writer learned from W. S. McGregor of Temple that the gravel-pit from which these remains were collected is in the first terrace, above the flood plain of the river, at an elevation of about 40 feet above the normal water-line and at a distance of about half a mile from the river.
>
> These vertebrate remains are indicative of early Pleistocene time, about that of the first interglacial. It seems to follow that, whatever the geological age of the terrace itself, the materials which inclosed those fossils belong to the early Pleistocene and equivalent, or nearly so, to the Sheridan beds. The explanation may be that late in the Pliocene, or more probably very early in the Pleistocene, a broad and deep valley had been excavated along Leon River. A period of depression began and continued until the materials of the highest Pleistocene terraces had been laid down and the old channel itself

[31]Hay, O. P., 1923. Pan-Amer. Geol., XXXIX, p. 116, pl. XIII.

[32]Hill, R. T., 1901. U.S. Geol. Surv., 21st Ann. Rept., pt. 7, p. 354.

[33]Hay, Oliver P., 1924. Carnegie Inst. Publ. 322-A, pp. 223, 228, 243.

filled up. As the filling of the valley proceeded, animals were buried in the deposits. Although during a later period of elevation, the river removed the greater part of the earlier sediments, some of these yet remain in the terraces. It seems to follow that possibly the fossils in such materials in the lower terraces are somewhat older than those in the upper terraces. It is to be remarked, however, that some parts of each terrace may belong to the time of the original excavation, others to the time of refilling, and others perhaps to the time of re-excavation.

Deussen lists the terraces on Little River as follows:[34]

Terrace No. 1, composed of brown silt and loam; 32 feet above bed of stream at Cameron.

Terrace No. 2, dark silt and loam; 42–48 feet above bed of river; poorly exposed at Cameron, also exposed in the vicinity of Temple.

Terrace No. 3 is 78 feet above the bed of the river, and it is represented by a flat 2½ miles wide near Holland.

Terrace No. 4, composed mostly of limestone gravel; 104–108 feet above the bed of the river; exposed in vicinity of Temple; Cameron is built on it.

The Uvalde terrace is veneered with a thick coat of flint gravel; it lies 250–258 feet above the bed of the river; it is well shown southeast of Temple, at Bartlett, and at Buckholts.

Dr. Hay[35] reported from a gravel pit near Rogers *(a)* some horse teeth, the left upper third or fourth premolars, of possibly *Equus leidyi;* and *(b)* other horse bones, right ischium, acetabulum, and a metacarpal, stated to have come from a depth of 25 feet.

STRUCTURAL GEOLOGY

It is known that in Bell County there are present certain metamorphic pre-Comanchean rocks which indicate considerable deformation, probably mountain-making in character. After the deposition of these rocks and the orogenic movements there was denudation over a widespread area in central Texas. In the Central Mineral Region, Cambrian and Cambro-Ordovician sandstones and limestones were deposited. None of these Cambrian rocks have yet been discovered in Bell County, and only one questionable record of the

[34]Deussen, Alexander, 1924. U.S. Geol. Surv., Prof. Paper 126, pp. 116–117.

[35]Hay, Oliver P., 1927. The Pleistocene of the western region of North America and its vertebrated animals. Carnegie Inst. Publ. 322-B, p. 297.

Cambro - Ordovician (Ellenburger) limestone. Following this deposition there took place during Silurian and Devonian times extensive planation of the land mass, producing a surface now generally referred to as the pre-Mississippian surface. During the Paleozoic a prominent land mass, called Llanoria, existed in east Texas and in Louisiana, and sediments resulting from its denudation were distributed northwards and westwards in the Pennsylvanian seas, to form the thick deposits which outcrop west of Bell County. From western Bell County on westwards in central Texas, the Ellenburger, Bend and Pennsylvanian occur underground in the sequence and lithology typical of the Central Mineral Region and in areas to the north of it. In central Bell County this sequence apparently thins eastward and becomes unrecognizable, and beneath the Cretaceous is found a series of slaty shales and quartzites of undetermined age. If these are Pennsylvanian they represent an abrupt change of facies from the Pennsylvanian of Coryell County, the next county to the west. If they are pre-Cambrian, they have been greatly elevated and the Pennsylvanian sediments have been removed. Until their age is settled it will be impossible to reconstruct the historical geology of Bell County.

Regardless of their age the black shale quartzite series forms a prominent underground belt, lying just beneath the Cretaceous and having an Appalachian trend, across central Bell County. Sellards has recently stated that:

"Some of the difficulties of interpreting underground records are simplified by assuming a southwestward extension under the Cretaceous of the Ouachita facies of deposition, folding and thrusting, such as is indicated by a line on the map. West and north of this line deposition in the early Paleozoic is that of an epicontinental sea with subsequent mild structural deformity. East and south of the line, early Paleozoic deposition may be, as in the Ouachitas, that of a geosyncline with subsequent violent folding and thrusting."[36]

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[36]Sellards, E. H., 1929. Preliminary map of the underground position of Pre-Cambrian in Texas. Bur. Econ. Geol., mimeogr. circ. no. 8, with 1 map.

Llanoria,[37] the source of sediments swept westwards and deposited in the Pennsylvanian seas, must have persisted through much of the late Paleozoic, until it became buried under the incroaching Comanchean sea in the Texas coastal Plain. There thus exists in the region three ancient land surfaces, representing large unconformities in the geologic column, that at the beginning of Cambrian or Cambro-Ordovician sedimentation, the pre-Mississippian surface which at some places is represented by the existing top of the Ellenburger limestone, and the pre-Comanchean surface.

The general regional structure therefore in Bell County, includes a high area of folded, faulted and metamorphosed rocks running out from the Central Mineral Region in a general Appalachian direction. West of this the Ellenburger, Bend and Strawn deposits come in with increasing thickness and in normal sequence. East of the high, no wells have yet penetrated the pre-Cretaceous, and the stratigraphic situation is unknown. It is known that at Luling the Cretaceous is directly underlain by schists of distinct pre-Cambrian appearance.

In western Bell County, the Thomas Young well demonstrates that the Strawn was deposited in a deep trough. From the northeast border of the Mineral Region, large faults trending toward Bell County disappear beneath the Cretaceous overlap. They or similar faults doubtless occur underground in Bell County, but have not yet been detected.

Bell County, which lies partly within the Gulf Coastal Plain as currently defined, has in its exposed formations a rather simple monoclinal structure and the Cretaceous strata dip in a southeast to easterly direction toward the Gulf. There are no visible surface faults of great displacement in the county. The prominent Balcones faulting seen in Travis County and southwards persists through Bell County as a general trend or zone, poorly defined in most places, and affects the structure mainly by marking a line east of which

[37]Miser, H. D., 1921. Llanoria, the Paleozoic land area in Louisiana and eastern Texas. Am. Jour. Sci., II, 61-89. Honess, C. W., 1923. Geology of the Southern Ouachita Mountains of Oklahoma. Okla. Geol. Surv., Bull. 32. Cheney, M. G., 1929. History of the Carboniferous sediments of the Mid-Continent oil field. Bull. Amer. Assoc. Petr. Geol., XIII, 557-594.

the dip steepens to about three times its usual amount in the Lampasas Cut Plain west of the Balcones zone. The Balcones Fault Zone in Bell County, in the sense used in this paper, is a belt averaging about 7 miles wide, passing through Georgetown, Prairie Dell, Belton, Pendleton, and on north-northeast to beyond Waco. No continuous fault lines have been traced in this belt. There are numerous separate, short faults having each the general trend of the belt. There are some cross-faults with a trend transverse to the belt. Some faults are arranged *en échelon*.

Near Belton this belt may be considered to be bounded on the west by the well-known fold or fault at the Santa Fe cut near the Kolls place, 2 miles northwest of Belton; and on the east by several small faults near the Mount Vernon school, about 5 miles south-southwest of Temple. In McLennan County the east boundary may be placed as a fairly persistent line of short, perhaps isolated faults, found in the creeks a short distance east of Lorena, Bruceville and Hewitt, and the west line is marked by the presumed faults along the Bosque Escarpment southwest of Waco.

These several faults in Bell County will be noted briefly. (1) About a mile west of Prairie Dell on the Farrell farm, a small area of disturbed dips in the tops of the Edwards. The exposure is too poor to detect clear faulting. (2) Along the east side of Smith's Branch a mile east of Salado is a small graben containing a tilted block of Del Rio, Buda, and Eagle Ford. It is bounded on the west by a straight fault a mile or less in length, with upfaulted Main Street limestone; on the east by upfaulted Buda forming a small west-facing scarp. Near its north end, the western bounding fault with Del Rio faulted against Main Street is clearly exposed. This graben is only about 100 yards wide; it has a Balcones trend. (3) About a mile south of Belle Plains school house, it is reported that in a cistern dug ten years ago calcite veins some trending northeast and some northwest were found, and that four wagon loads of calcite crystals were taken out. (4) About on the trend with the last are relatively large faults of about 75 feet displacement, downthrow to the west, in the east bank of Salado Creek

just west of the road and a short distance south of Dulaney's Crossing, on the E. W. Holland tract of the W. H. Walker survey. This and the last named fault are in the Austin chalk. (5) One mile east of the last, in the Austin chalk, faulting with a Balcones trend is reported. (6) Just south of Ferguson Mill on Salado Creek is a small horst of Weno and Main Street, with the Austin on the east boundary in contact with Main Street in the horst, and Del Rio clay bounding it on the west. This structure is *en échelon* with the one east of Salado. (7) Near Summers Mill some small scale faulting in the Austin chalk is reported. (8) Near the iron bridge of the Sparks-Holland road over Lampasas River 4.5 miles south-southeast of Belton, the Austin chalk comes to within a few feet of the level of the Del Rio clay, either by faulting or by overlap. From digging pits it was found to be impracticable to clarify the exact relations (see discussion of Buda limestone). This feature is in line with the Ferguson Mill faults. (9) In the Austin chalk gorge south of Mount Vernon church, are some small faults with a Balcones trend. The J. T. Reed well was located nearby. (10) In a stream a mile north of the last locality and between the Mount Vernon school and the Missouri, Kansas & Texas Railway, are some small faults in the Austin chalk. (11) At Shallow Ford on Leon River, 2 miles east of Belton, is a minor flexure in Georgetown, with asphalt and calcite in veins. (12) On the Santa Fe Railway near the John Kolls farm, 2 miles northwest of Belton, is a flexure or fault, in the Edwards limestone. At 256 feet in a water well on the Kolls place, heavy black oil was found on the water for years. Six wells have been drilled nearby.

There are some scattered outlying faults in the county. One of these is on the Bacon farm, V. L. Evans survey, in a small tributary of Noland Creek about 3½ miles east of Killeen and 2/3 mile south of the Killeen-Nolanville road, about ½ mile southwest of the Bacon Nos. 1 and 2 wells of the Nolan-Bell Oil Company. This is a small normal fault in the Walnut, trend about N. 40° W., downthrow 2½ feet to the west, dip northwest. In southwestern Bell County on the Killeen-Florence road 5 miles south of Lampasas River

(McBride bridge) and less than ½ mile north of the Williamson County line are steepened dips indicating faulting or folding.

In the region east and northeast of Rogers geologists in the employ of Robert R. Penn located a surface fault of trend N. 40° E., downthrow to west of about 35 feet on the Pecan Gap horizon, with no fault in Austin chalk. It is likely that in northern Bell County near Eddy the southward continuation of the Hewitt-Lorena-Bruceville faulting can be detected in stream cuts.

There are doubtless numerous other faults in the Upper Cretaceous in eastern Bell County.

The part of Bell County east of the Balcones faulting above described lies in the general graben bounded by the Balcones system on the west and by the Mexia fault line to the east. In this graben, small discontinuous faults, many of them arranged *en échelon,* are known from several counties, and the data here presented agree with finds elsewhere in this graben.

On Middle Darr's Creek 3½ miles west of Holland, a fault in the Austin chalk has a trend of about N. 35° E., with a downthrow to the east; west of the fault there is a strong west dip; the displacement is apparently not great. A mile south of this locality, a fault crosses South Darr's Creek with about the same trend.

ECONOMIC GEOLOGY

WATER

The main water resources of Bell County are artesian water and impounded stream water. In rural districts where only a small supply is demanded, shallow surface wells with a dependable source, available even through pumping, are in demand. With the increasing exploitation of the formerly prolific artesian reservoirs (as the Trinity water strata) and with the rapid growth of cities, the water supply problem has shifted from the limited possibilities of artesian supply to the possibilities of impounded surface water. Thus cities

in central Texas which formerly relied largely upon a combination of Trinity water, first utilized in the late 80's and for many years found sufficient for city needs, and river water, have turned to impounding projects designed to supply needs for a long series of years in advance. Modern water problems therefore are concerned only in part with artesian possibilities, an essentially geologic problem, but also with questions of drainage, run-off, contamination and reservoir sites, essentially engineering problems. It is only the geologic aspects of water supply in Bell County which are here summarized.

Springs: The water resources include springs, which are widespread over Bell County, but in the aggregate are of little economic importance. Some of the more prominent of these are as follows:

Abbott Spring, 8½ miles west of Prairie Dell and 1 mile north of the Williamson County line; a gravity spring in the Walnut; source from the Edwards-Comanche Peak escarpment.

Ransomer Spring, 4 miles northwest of Nolanville; gravity spring in the Comanche Peak limestone.

Three Chimneys Spring, 3½ miles west of Salado, on Mustan Creek; a gravity spring in the Comanche Peak limestone.

Salado, several springs in bed of Salado Creek. Fissure springs in the Edwards.

Miller Spring, 3 miles north of Belton; in the Edwards.

Bluff Spring, 2½ miles south of Belton, and ⅓ mile east of the KT highway; horizon, Edwards.

Summers Mill; seep spring in Austin chalk.

Buchanan Park, ⅔ mile east of Little River; large gravity spring in Austin chalk.

Besides these there are several Bell County place names which suggest springs, likely of the gravity or seep type, as Elm, Mountain, Mud, Sulphur, and Willow springs.

Impounded waters: The State Board of Water Engineers has already made topographic sheets, on the scale of 1:24 000, of the courses of the Little, Leon and Lampasas rivers across Bell County, the only stream valleys in which large scale impounding operations would likely be attempted.

Artesian waters: There may be some sporadic water levels in the Pennsylvanian or other Pre-Cretaceous rocks,

but these are local or else of small volume or economic importance. In addition, in most parts of the county there are available surface or shallow ground waters in the outcropping Cretaceous formations or in the Pleistocene sand and gravel mantle.

The following typical wells give some information about depths to the main water horizons in Bell County.

Winans and Forbes, Ferguson 1 (in Tennessee Valley, 5 miles northwest of Belton, elevation 550 feet): Water gravel 340–346 feet (=Glen Rose); sand and gas 708–722 (=Basement sands); Trinity waters not logged.

Holcomb well (Lewis Walker surv., 3 miles west of Belton): Water 380–420, 480–510 (?Glen Rose); sand and gravel 1065–1105 (=Basement sand).

Kolls (Down, Perry and Hughes), 2 miles northwest of Belton: Gray lime, water, 85–110 (?Comanche Peak); sandy lime, water, 435–475 (=Glen Rose); white sand, water standing within 40 ft. of top, 920–946 (1st Trinity); white sand, water, at 1048–1065, 1130–1132, 1134–1135, 1136–1182 (Trinity basement sands).

J. T. Reed 1 (about 5 miles south southwest of Temple): Sand 690–720 (?Comanche Peak); water 1005 (?Glen Rose).

J. B. Smith, Edds 2 (about 1 mile east of Heidenheimer): Water 910 (Georgetown); sulphur water 1155 (Edwards).

Holland City well (2 blocks west of M. K. & T. station): 25–31 ground water, fresh; limestone with slightly salty water, 806–836 (Georgetown?); sulphur mineral water, flowed, 990–1044 (Edwards?); fresh water, rose 7008 in hole, 1115–1121; fossiliferous limestone with considerable fresh water, 1165 (this water rose to top, flows a small stream); analysis of water sampled at 1032 feet follows.

Analyses of Waters from Holland City Well

	1000-Foot water			1032-Foot Water		1400-Foot	Trinity Water	
	A ppm.	B ppm.	B gr/gal.	ppm.	gr/gal.	ppm.	ppm.	gr/gal.
Siliceous residue	162	----	----	38	2.22	20	----	----
Iron and Aluminum oxides	11	----	----	Trace	Trace	20	----	----
Ions:								
Calcium	413	157	9.2	137.4	8.01	179	72	----
Magnesium	117	70	4.1	77.1	4.49	100	46	----
Sodium	1749	----	----	1953.3	113.90	2021	----	----
Carbonate	----	----	----	192.6	11.20	548	----	----
Bicarbonate	----	----	----	----	----	40	----	----
CO^2	105	----	----	----	----	----	----	----
Sulphate	2048	2640	----	2910.7	127.60	452	1024	----
Chloride	1005	1000	----	1050.0	60.95	1840	309	----
Organic and volatile	420	----	----	----	----	----	----	----
Total	6030	5860	343.0	6359.1	328.37	5310	2410	----
Hypothetical Combination:								
Calcium carbonate	----	----	----	321.0	18.70	178	292	17.0
Calcium bicarbonate	----	537	31.4	----	----	----	----	----
Calcium sulphate	1003	82	4.8	31.3	1.82	89	----	----
Magnesium sulphate	66	346	20.2	381.0	22.21	120	----	----
Magnesium carbonate	201	----	----	----	----	----	----	----
Magnesium bicarbonate	----	----	----	----	----	----	267	15.6
Sodium sulphate	2509	3410	226.5	3932.3	229.30	522	1515	89.5
Sodium chloride	1658	1650	96.5	1732.5	102.00	2964	510	29.5
Sodium carbonate	----	----	----	----	----	951	----	----
Sodium bicarbonate	----	----	----	----	----	146	----	----
Silica	----	----	----	----	----	20	----	----
Iron and Aluminum	----	----	----	----	----	20	----	----
Soap hardness	507	----	----	----	----	----	----	----
Total alkalinity	387	----	----	----	----	----	----	----
Turbidity	350	----	----	----	----	----	----	----

OIL AND GAS

Shows of oil and gas are known from Bell County. Pervious subsurface horizons are as follows, among others: Trinity (Basement) sands, at least 3 principal horizons, mainly bearing fresh water; Glen Rose, one or more pervious horizons; basal Edwards, a porous horizon; top of Del Rio, a local water horizon; Georgetown, water horizon.

Horizons producing oil shows are: Eagle Ford shale, Walnut clay. It is not impossible that certain black Pre-Cretaceous shales, Pennsylvanian or other, or porous horizons continuous to them, should produce some oil. The Pre-Comanchean black shales show traces of oil.

Most wells so far drilled in Bell County have not been located with sufficient regard to geologic structure in the Cretaceous. The sub-surface Pre-Cretaceous structural outlines are not yet clear except in a very general sense. Hence previous drilling does not condemn Bell County as potential oil territory.

Surface indications of oil, gas or bitumens: Gas seeps reported from small creek emptying into Lampasas River, right bank, practically at Bell-Burnet county line; The Narrows; Warrick place; spring near Dice (Three Rivers). Reported oil seeps: The Narrows; Mud Spring. These are all unverified. Oil shows in wells occur on the Kolls place 2 miles west of Belton, and on the Edds place east of Heidenheimer (In Edds No. 1, from the Eagle Ford). Asphalt and calcite in joints reported from Leon River at Shallow Ford 2.5 miles east of Belton.[37a]

Drilling in Bell County dates from about 1881, when the Standard Oil Company drilled a 700-foot hole at the old Ratliff homestead near The Narrows; no oil was found; the well now flows salty water used for cattle. In about 1886–1890 the Standard drilled a well near Dunn's Canyon a mile north of the Santa Fe Railway; depth was stated to be about

[37a]Surface indications of oil have been reported for years from western Bell County. Dr. S. B. Buckley (First Annual Report of The Geological and Agricultural Survey of Texas, Houston, 1874, p. 44) says: "During Governor Throckmorton's administration, I visited some oil springs in the western part of Bell County, which were also coated with oil to some extent, but the supply was not as abundant as near Melrose."

700 (?) feet; water and traces of oil now rise to the surface from the old hole.

The Spanhel well at 890 feet was rated at 10 barrels per day of oil. The Kolls Garrison well was stated to have an 8-foot oil sand near the base. The Kolls No. 2 (Producers) drilled to 1177 feet, eight months after having been abandoned, developed gas pressure, blew off two upper joints of casing, and caved in. The Kolls, Bell-Williamson well is reported to have had gas at 1205 feet. There are several other wells in which gas and oil have been reported in Bell County.

LIMESTONE

The main commercial limestones of this county occur in the following formations: Glen Rose, Comanche Peak, Edwards, Georgetown, Buda, Austin Chalk. Of these the Buda is a formation of insignificant thickness and considerable porosity, and is of use mainly for road metal and for terracing. The others are thick and widespread formations, at most places accessible to railroads.

The Glen Rose is mainly thin to medium-bedded limestone, in part magnesian, fairly hard, with mostly very little clay interbedding. It outcrops in the Brookhaven area and in the Maxdale area as far down Lampasas River as Youngsport, in regions inaccessible to railways.

The Comanche Peak is a gray-white, medium soft limestone mostly with compressed nodular bedding, and mostly not bedded in continuous strata. It occupies a north-south strip beneath the Edwards in the west-central part of the county, where it makes a continuous outcrop across the county from above Brookhaven to the county line southwest of Youngsport. It crosses the Santa Fe Railway (San Angelo branch).

The Edwards is a hard nearly pure limestone, well bedded in strata of medium to massive thickness. Its outcrop lies just above that of the Comanche Peak limestone, caps the scarps and outliers in western Bell County and from Belton west to Nolanville is accessible to the Santa Fe Railway.

The Buda is a thin, porous, shelly limestone less than 5 feet thick, outcropping in a narrow irregular north-south strip across the center of Bell County. It is best developed along the KT highway south Salado, and economically is only of local importance. The limestone flags in the middle of the Eagle Ford are likewise thin, and of only local use.

The Austin Chalk outcrop occupies a wide, continuous band in the east-central part of Bell County. It underlies much of the Black Prairie and is economically one of the most important formations in the county.

Utilization of Bell County limestones.—These limestones may be used for building stone, quick lime, road metal, concrete aggregate, portland cement, carbon dioxide manufacture, uses requiring exceptionally pure limestone (for certain layers of the Edwards), scouring materials, and other uses.

For *building stone,* most of the Glen Rose and Edwards limestones are available. They were so used in the earlier days of Bell County, which lies in the prominent belt of stone houses marking the Cretaceous limestone outcrop in central Texas. These two stones have excellent cleavages, split to sufficiently thin strata, are hard, resist erosion and disintegration, are easily worked by chipping or sawing, retain a pleasing color and are compact and relatively impervious to moisture.

As crushed stone, the Edwards is in certain levels hard and compact, and can be used for *road metal* and for ballast and *concrete aggregate.* With demand, certain Glen Rose strata in the western part of Bell County could be similarly used. The soft Walnut and Austin limestones are used for local road repair and filling.

Portland cement requires, in addition to the very necessary market conditions of the proposed plant, certain combinations of material, specifically limestone and clay, which are abundant and suitably located in respect to transportation, in Bell County. Many places along the contact of the Eagle Ford shale and the Austin Chalk fulfill the technological requirements for Portland cement. This contact crosses every railroad in the county. From the McLennan County

line south to Pendleton (where it crosses the Santa Fe) it is nowhere more than 1½ miles distant from either the Santa Fe or the Missouri, Kansas and Texas Railway. From Pendleton it turns south, roughly paralleling the Santa Fe, which it crosses a mile west of the city limits of Temple. From here it passes due south and crosses the Missouri, Kansas and Texas Railway (Belton branch), about midway between Belton and Temple. Thence it passes southwest by Armstrong School, through points 1½ miles east of Salado, ½ mile east of Prairie Dell, to near Jarrell, capping the west-facing scarps of the Black Prairie upland and lying several miles from the Missouri, Kansas and Texas Railway.

The Georgetown-Del Rio boundary offers similar opportunities for Portland Cement in Bell County. This contact parallels the Santa Fe Railway from the McLennan County line one mile north of Stampede Church to Midway Church, and lies about two miles west of the railway. The contact passes from Jones Mill southwest to just east of Salado and thence near the KT highway to the Williamson County line south of Prairie Dell.

Many members of the Georgetown formation offer good combinations of raw material for Portland cement. Such are the mixed clay-limestone and clay-marl of the Weno member, the Denton-Fort Worth combination, and the Fort Worth-Duck Creek combination. These are best accessible to railroads at various points from Belton to Midway Church on the Santa Fe, Belton to the Leon River railway bridge on the Missouri, Kansas and Texas Railway, and at various points along the tall cliffs bordering the south bank of Noland Creek between Belton and the mouth of the creek.

The Walnut-Comanche Peak contact equally affords the necessary combination of materials. It crosses the Santa Fe near Stone Siding about 3 miles west of Belton, and thence west to the county line west of Killeen is not more than 2 miles from this railway. The Walnut-Glen Rose contact, a similar possibility, is not near existing railroads in Bell County.

For *quick lime,* most of the limestone formation in the county already cited may be used. The purest limestone is

in some of the harder, or in some of the more coquina-like, Edwards strata. This outcrop occurs in proximity to railroads between Belton and Nolanville. Similar conditions obtain, and the same outcrops are suitable, for *carbon dioxide manufacture.*

High purity limestone occurs in many Edwards outcrops, which have been already described, in the form of *(a)* hard, pure, strata; *(b)* coquina, or shell aggregate; and *(c)* redissolved, practically pure, calcium carbonate in pulverulent form, interbedded in the Edwards formation. These occur west of Belton near the railway. The following analysis of the pulverulent layers (from the Kolls farm, 3 miles west of Belton) indicates the composition of such layers:

	Per Cent
Silica	3.10
Al_2O_3	.05
Fe_2O_3	1.20
CaO	51.80
Sulphuric acid	.80
Loss (mainly CO_2)	41.60

Analysis by Ministière de l'Instruction publique et Beaux Arts, Paris, 1920.

Other Edwards samples from nearby give on analysis over 99% of calcium carbonate. Such relatively pure limestone is available in Bell County in unlimited quantity. It can be used for scouring and cleaning powder, and as a light abrasive.

CLAY

These consist of shale, clay, marl (=calcareous clay), and bentonite. The main *clay* formations in Bell County are: Walnut, Del Rio, Eagle Ford, Taylor. Special technological investigation, burning tests and analyses, are necessary to determine the exact uses of any particular clay sample. In general it can be said that for *brick*, most shales of the Eagle Ford formation, many clays of the Taylor except those located close to chalk members, and some clay layers of the Walnut (avoiding the shelly layers and screening out excess lime and shells where necessary) are generally available. The Del Rio contains some pyrite, ironstone and limy

shells, and will burn to a red building brick. One formation on which there should be special technological and burning tests to determine if there are not special levels or deposits which burn to a high-grade face brick, is the Eagle Ford shale. Particularly the basal part of this formation, below the middle limestone flag member, should be investigated: it is practically non-calcareous and has an inappreciable amount of shell material. It is exploited at one place, on the Hill-McLennan county line. In Bell County its outcrop crosses the Santa Fe between Belton and Temple.

BENTONITE

Bentonite occurs in the Eagle Ford formation in Bell County, in thin seams mostly not over a foot thick on the outcrop, interbedded between strata of shale or in the limestone flag member. At present its economic exploitation would not be profitable, but it is worthy of record.

Burning tests will doubtless reveal other uses for Bell County clays. Some of them should be useful, alone or in combination, for roofing and interior tile, drain tile, earthenware, some pottery, and for other uses.

SAND AND GRAVEL

Bell County, especially in its eastern part, has unparalleled resources in sand and gravel, probably as rich as any county in central Texas. These are of two types: *(a)* upland terraces, which are at most places most accessible; and *(b)* low terraces, or recent stream bed deposits. These deposits are extensive and widely scattered, particularly in eastern Bell County, where the upland gravel terraces overlie Austin chalk or Taylor marl.

Such gravels are extensively worked for roads, and in addition to their being located in the Black Land Belt where they are of most use, their wide distribution renders them easily accessible to short hauls. Many of the gravels and sands are locally somewhat sorted. The sands are of various sizes. The deposits are thick, reaching 50 feet or more. In central and western Bell County the abundant creeks and rivers make available many deposits of stream gravel.

METALLIC ORES

Such ores are rare and local in Bell County, but some occurrences seem undoubted. Most of them are reported from a narrow zone in the strike of the formations extending from about the Warrick farm on Rumsey Creek, several miles west of Prairie Dell, north-northeast to The Narrows, and still farther to points northeast of Nolanville. On the Ben F. Warrick place, there were old metal workings and machinery supposed to date from the Spanish occupation. About 1870 Messrs. Hall, Hyatt and Berringer reopened operations at this spot. Galena is reported from Rumsey Creek a short distance downstream from the Warrick place. Galena and lignite are reported from The Narrows. There is also a report of cinnibar specimens from the Rumsey Creek region.

COAL

There are some reports of coal occurrences, which should be checked. On the Maxwell farm, on the south side of Lampasas River a mile upstream from Comanche Gap, a 14-foot bed of coal is stated to occur in a well. At a locality 6 miles south of Belton a seam of coal is reported in a well at a depth of 50 feet. These were not verified. The first mentioned occurrence would be in the Glen Rose formation.

Volcanic Ash: Mr. Stone, County Superintendent, reports volcanic ash from a small creek on or near McFaddin ranch, near Phoenix School, about 12 miles northwest of Belton. The thin seams of bentonite-like material in the upper Eagle Ford formation have been noted.

WELL DATA

SUMMARY OF WELLS

WELLS ENTIRELY IN UPPER CRETACEOUS

Well:	Location:	T.D.	Elev.	Surface Form.	Ended in
H. G. Hendrick 1	1.5 mi. SW. Rogers	1200 *or* 1300	506[a]	Kta	Kef?
W. K. Hill 1, Pure (core test)	3 mi. WNW. Rogers	1035	612	Kta	Kef

WELLS ENDING IN COMANCHEAN

E. Fowler farm	7 mi. E. Bartlett	1374?	596	Kta	Kgr?
Frank Ancniec 1	2 mi. NW. Red Ranger	800	------	Kta	Kef
C. F. Anderson 1	4 mi. W. Salado	560+	------	Ked	Kgr
Bell County	Jail, Belton	890?	525[t]	Ked	Ktp
Burris 1, Merchant	12 mi. WSW. Belton	552	------	Kwa	Ktp
J. S. Darnall 1	4 mi. E. Holland	1075	534	Kta	Kdr?
Jim Edds 1, Three States Oil Co.	1⅛ mi. E. Heidenheimer	925+	556[a] *or* 558	Kta	Kdr?
Jim Edds 2, J. B. Davis	Same	1155	550[a]?	Kta	Ked
Rufus Hardy 1, R. R. Penn	3.2 mi. NE. Rogers	1457	458.6	Kta	Kgt
Rufus Hardy 2, R. R. Penn	Same	2988	485.3	Kta	Ktp
Holland city water well	Holland	1993	523	Kta	Ktp
Mosley 1, J. H. Riley	1¼ mi. WSW. Heidenheimer	740	563	Kta	Kef
J. T. Reed, Indian Oil Co.	5 mi. S. Temple	1005	570	Kau	Kgr
Frank Spanhel 1, Camp Elm Oil Co.	2½ mi. NW. Red Ranger	2262	453	Kta	Ktp?
Ratliff 1, Standard Oil Co. (A)	The Narrows, 1881	700	600?[t]	Kwa	Ktp?
Standard Oil Co. (B)	Dunn's Canyon	700?	600[t]	Ked	Kgr?
Tom Talasek, B. C. Vickers	Ratibore, 6 mi. N. of Red Ranger	1900	------	Kta	------
Troy city water well	Troy, 1923–1924	1731	680[t]	Kau	Ktp
Temple, artesian well	Temple 1890?	1900?	700[t]	Kau	Ktp
W. S. Stanfield 1	4½ mi. N. Temple	1210?	------	Kau	Kgr?

a=aneroid.
t=topog. map.

Well:	Location:	T.D.	Elev.	Depth Base Cret.	Surface Form.
	WELLS ENDING IN PRE-COMANCHEAN				
Wm. Bacon 1, Nolan-Bell Oil Co.	3.9 mi. W. Nolanville	2962*	820[a]	896	Kwa
Wm. Bacon 2, Nolan-Bell Oil Co.	Same	1820	820	896	Kwa
Noah Bailey 1, Mellon Oil Co.	7 mi. SE. Killeen	2790	700[a]	798	Kwa
Epperson 1	4 mi. N. Whitehall	960	690	722—	Kms
D. W. Hair 1, Rio Grande Oil Co.	2¼ mi. NW. Belton	2002	625[t]	1157	Ked
J. R. Holcomb 1, Bell County Oil Co.	3 mi. W. Belton, Dog Ridge	1640	760[t]	1107	Ked
John Kolls 1, Petoskey	2¼ mi. NW. Belton	937?	625[t]	-----	Ked
John Kolls 1, Empire (Garrison)	Same	995	625[t]	-----	Ked
John Kolls 2, Producers	Same	1177	625[t]	-----	Ked
John Kolls 3, Bell Williams	Same	1405	625[t]	*	Ked
John Kolls 4, Down, Perry and Hughes	Same	1446*	625[t]	1194	Ked
Ludwick 2, Stanfield	1 mi. NNE. Bland	1510	600[t]	1200	Kwa
Owens 1, Eclipse Oil Co.	Youngsport	1000	650[t]	-----	Kgr?
Sladen 1, Eclipse Oil Co.	Near Killeen	-----	900	-----	Kwa
Sladen 2, Eclipse Oil Co.	7 mi. S. Killeen	1216	900[a]	-----	Kwa
Swope 1, Killeen-Bell Oil Co.	-----	-----	888[a]	850 *or* higher	-----
Ben F. Warrick 1, Bell-Williams Oil Co.	6.7 mi. NW. Jarrell	1373	864[a]	-----	Ked
Ben F. Warrick 1, J. B. Hartman et al.	6.8 mi. NW. Jarrell	2772	944[a]	973?	Ked
Winans and Forbes 1 (=Ferguson 1)	-----	1780	550[t]	789 *or* 821	Kwa
Thos. Young 1 (=KC. well)	-----	2895	800[t]	761?	Kwa

a=aneroid.
t=topog. map.
*Reported to have ended in "black limestone" [probably pre-Comanchean, of the Black Shale-Quartzite series].

DESCRIPTION OF WELLS

Frank Ancniec 1, drilled by Ira P. Wilson. Location: 10½ miles east-southeast of Temple, 2 miles northwest of Red Ranger, ½ mile east of Spanhel well. June, 1925–February 16, 1926. Rotary. Surface formation: Taylor. T. D., 800, in Eagle Ford. Elev.: ?.

The most likely interpretation of this well, from the log alone is: Taylor, soft, 0–560; Austin, harder, 560–750; Eagle Ford, hard, 750–800.

J. S. Darnall No. 1, 4 miles east of Holland; elevation 534.

No data at hand for separating Taylor from Austin. Mr. Darnall stated that the well had "dark shales since 985"; top of Eagle Ford may be at 985. Another statement says: "Above 657 the formation was light colored; below that it was mostly dark, with some strata of gray and brown" (letter, December 13, 1915).

Gray to stony marl, fragments of *Gryphea. Ostrea congesta (?)*, and *Inoceramus*. Possibly Austin chalk	930 *or* higher
A show of gas, at	985– 987
Gray marl of fine, slimy texture, with scattered sand grains; some almost black shale or clay mixed in; fish vertebrae	1020
Dark fine-textured marl; and gray coarse textured marl containing spines, fish teeth, scales, vertebrae; a profusion of foraminifera; inocerami, oysters, bentonite pyrite, *quartz pebbles*. Evidently Eagle Ford	1065
Quartz pebbles, most of them pink, some white; echinoid spine	1055–1075
Gray coarse marl, many foraminifera, fish scales	1055–1075
Light gray chalk-like rock, and a few fragments of pure white harder chalk-like rock; large oyster shell fragments	1055–1075

The quartz pebbles above recorded suggest the Eagle Ford-Del Rio unconformity, but there is no positive evidence of Del Rio.

Jim Edds, Three States Oil Company; drilled 1920–January, 1921. Location: 1⅛ mile due east of Heidenheimer, about 200 feet southeast of Edds No. 2. Rig: cable. Surface formation: Taylor. T. D., uncertain, 925+ feet. Elevation: about 550. Casing: 12″ at about 85 feet; 8″ at about 900± feet. No water to 900 feet.

The data on this well are largely quite unreliable. The nearby Edds 2 was carefully sampled from 700 feet down, and will serve to give the section at this locality; therefore the following supposed facts about Edds 1, are here included only for purposes of record.

Edds 1 was reported to have 390 feet of Taylor, a figure much too high: it is about on the strike of the Holland well, which presumably has 150 feet of Taylor; and the Hill Pure core test, down dip from the Edds well has only 373 feet of Taylor; the Edds 2 has 170 feet. In Edds 1, the base of the Austin chalk is variously reported at 650 and at 780; in Edds 2, it is at 736 feet. Black Eagle Ford shale, some of

it of the splinter shale variety, is reported from as high as 780 and as low as "850 or 950"; its base in Edds 2 is at 915. Its most probable base in Edds 1 is at 925 feet,[38] because at this depth the last oil show was reported, and below that was "broken lime and shale." Conformable to this interpretation, the hard ledge with pyrite reported at 800–804 would be Eagle Ford flags.

Jim Edds 2, J. B. Davis. Location: 1⅛ miles due east of Heidenheimer. November, 1928–May, 1929. Rig: cable. Surface formation: Taylor. T. D., 1155, in Edwards. Elevation: 556a. Casing: 940 feet of 8". Waters: 1155, heavy sulphur water (Edwards). Samples 703–1155 in Bureau of Economic Geology.

Correlation from log and examination of samples: Taylor, 0–170=170+ feet; Austin, 170–736=566 feet; Eagle Ford, 736–915=179 feet; Buda, 915–916=1 foot; Del Rio, 916–995=79 feet; Georgetown, 995–1085=90 feet; Edwards, 1085–1155=70+ feet. The Buda is assigned a nominal thickness of 1 foot from cavings.

D. W. Hair 1, Rio Grande Oil Company, Lockhart & Co., E. T. Green (Brownwood), drilling contractor. September 28–December 10, 1929. Cable, Fort Worth spudder, model J. Location: 2¼ miles northwest of Belton, north side of Santa Fe track, opposite John Kolls place. Surface formation: Edwards. T. D., 2002, in unidentified pre-Cretaceous rocks. Elevation: 625 feet. Casing: 15½", 205⅓ feet; 12½", 1000 feet; 10", 1132 feet. Waters: 375 feet, 1 bailer soft water per hour; 545 feet, increased to 2 bailers per hour; 883–885, water to within 100 feet of top of hole; 1008–1015, water sand (Trinity); 1022–1060, water sand (Trinity); 1132, water broke in around 10" pipe, put in 1 joint 10".

Provisional correlation (from log only): Edwards-Comanche Peak, 0–150; Walnut, 150–243=93 feet; Glen Rose, 243–870=627 feet; Travis Peak, 870–1157=287 feet; unidentified pre-Cretaceous rocks (quartzite, indurated shales), 1157–2002. Reported mostly hard rock to T. D., but some shale near bottom of hole. Samples in Bureau: 1132–1305, 1305–1310.

K. H. Hill 1, Pure Oil Co., core test, Sullivan core outfit. Location: South side Little River-Rogers road, on west side of "The Knobs," 3 miles west-northwest of Rogers. November–December, 1929, abandoned December 12, 1929. Surface formation: Taylor. T. D., 1035, in Eagle Ford. Elevation: 612 feet.

Correlation: Taylor clay, 0–338; Taylor chalk marl, 338–373; Austin chalk, 373–977=604 feet; Eagle Ford, mostly salt-and-pepper shale, 977–1035=58+ feet. Cores in Bureau of Economic Geology.

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[38]The 8" casing was set at about 900 feet, in this region, the extreme caving of the Eagle Ford often necessitates a casing near the base of that formation.

The base of the Austin is marked by a 2" layer of black angular shale chunks (Eagle Ford) and phosphatic nodules and fossils including a *Baculites*, reworked into and surrounded by a light gray chalk matrix; this zone overlies, with an irregular contact, the black Eagle Ford shale.

Holland city water well 1. Location: City of Holland, 2 blocks west of Missouri, Kansas & Texas Railway station. Date, 1929, about March to October. Rig: cable. Surface formation: Taylor. T. D., 1993, in Travis Peak. Elevation: 523 feet. Casing: 12", 35 feet; 8", 1048 feet; 6⅝", 1240? feet; 5 3/16", 1912? feet. Waters: 25–31, surface waters; 806–836, slightly salty water (Buda or Del Rio); 990–1044,[39] mineralized sulphur water; flowed (Edwards); 1115–1121, fresh water, rose 700 feet in hole (Walnut, quartz gravel); 1165, flowed (Walnut?); 1400,[39] water (Glen Rose); 1800–1805, water (Glen Rose); 1912–1965,[39] fresh water, flowing about 40 gallons per minute, temperature about 110° F. (Trinity). Well samples in Bureau of Economic Geology.

Correlation from sample examination (in part from driller's log): Taylor, 0–150=150+ feet; Austin, 150–625=475 feet; Eagle Ford, 625–806=181 feet; Buda, 806–810?=4? feet; Del Rio, 810–890?=80? feet; Georgetown, 890–990=100 feet; Edwards, 990–1044=54 feet; Comanche Peak, 1044–1066?=22? feet; Walnut, 1066?–1248=182 (possibility top Kgr at 1165); Glen Rose, 1248–1912=664 feet; Travis Peak, 1912–1993=81+ feet.

There is no direct evidence, from either samples or log, of any Buda in this well; however, it probably exists.

Ludwick 2, W. S. Stanfield. Location: 1 mile north-northeast of Bland. Jesse Pruitt survey, abstract 647. Drilled 1923. Cable rig. Surface formation: Walnut. T. D., reported at 1510, in undetermined hard rock. Bureau has 3 samples, at 785, 791, and 821 feet (all Travis Peak).

Driller reported two water strata, at about 1100 and 1200 feet; below 1200, hard rock was reported.

Mosley 1, J. H. Riley, driller. Sanchez survey, 1¼ miles west-southwest of Heidenheimer. June, 1929–February, 1930. Spudder, C model, with 2000 feet cable. Surface formation: Taylor. T. D., 740+. Elevation: 563±. Casing: 8", 740 feet (underreamed 700–740). Water: None, to 715 feet. Samples in Bureau: 470–715.

Provisional correlation: Taylor, 0–95?; Austin, 95?–600=505 feet; Eagle Ford, 600–740+=140+ feet.

J. T. Reed, Indian Oil Company, Joseph A. Williams, Geologist. Location: Maximo Marino survey, Moses Guffin part, J. T. Reed farm,

[39]For analyses of these waters, see discussion of water resources.

just south of Mount Vernon church, and 5 miles a little west of south of Temple. May–June, 1929. Rig: cable. Surface formation: upper Austin chalk. T. D., 1005, in Glen Rose. Elevation: 570. Casing: no record. Waters: in Georgetown, in Edwards, and a Glen Rose water around 1005 feet. Samples in Bureau of Economic Geology.

Correlation from samples: Austin, 0–325=325+ feet; Eagle Ford, 325–489=164 feet; Buda, 489–490=1 foot (only a minute amount of caving; assigned thickness 1 foot); Del Rio, 490–565=75 feet; Georgetown, 565–660=105 feet; Edwards, 660–765=105 feet; Comanche Peak, 765–810=45 feet; Walnut, 810–900=90 feet; Glen Rose, 900–1005=105+ feet.

Frank Spanhel 1, Camp Elm Oil Company, drilled by Ira P. Wilson. Location: William Woodford survey, 10 miles east-southeast of Temple, 2¼ miles northeast of Stringtown, 2½ miles northwest of Red Ranger. April, 1924–March, 1925. Rotary. Surface formation: Taylor. T. D., 2262, in ?Travis Peak. Elevation: 453 feet.

Most of the available information on this well is difficult or impossible to interpret. The log gives 540–684 as Austin chalk; cores labeled 685, 700?, 725, and 735 feet are apparently Austin chalk. The interval 540–735 may be Austin chalk. Eagle Ford, Buda and Del Rio are not clearly identifiable. Cores labeled 1100± and 1300+ are apparently Georgetown. At 2125 cuttings of Georgetown limestone and Del Rio clay with *Exogyra arietina* were submitted. At 2240 a mineralized water, possibly in the Travis Peak, was reached.

W. S. Stanfield 1. Location: about 4½ miles of Temple on east side of Waco road. Drilled 1924. Cable rig. Surface formation: Austin chalk. Depth: 1210 feet or more (900 according to one report). Bureau has two samples: 1100 (dark gray, finely micaceous rock, of undetermined age; and 1210 Glen Rose).

Driller's log follows:

Soil, to	2	Shale or clay	785
Austin chalk, to	4	White lime and shells	805
Blue marl, to	270	Dark gray lime	858
Eagle Ford shale; oil	520	Blue shale	955
Gray limestone	570	Thin white lime and shells	1056
Gray lime and shells	590	Gray lime, and shale breaks	1185
White lime and shells	707	Same	1210
Gray shale or clay	715	Glen Rose limestone, at	1210
White lime	740	T. D., 1510.	

INDEX